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Reconstrucción de estrategias de explotación de recursos animales por el ser humano: una propuesta metodológica

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RECONSTRUCCIÓN DE ESTRATEGIAS DE EXPLOTACIÓN DE RECURSOS ANIMALES POR EL SER HUMANO:

UNA PROPUESTA METODOLÓGICA

Tesis Doctoral

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SÍNTESIS

Los criterios que actualmente encontramos para reconstruir determinadas actividades de subsistencia llevadas a cabo por los seres humanos sobre carcasas adquiridas en actividades cinegéticas no son suficientes para saber con la mayor certeza posible qué estaba ocurriendo en algunos yacimientos. El objetivo principal de este trabajo es dar respuesta a aquellas cuestiones difusas que hacen que no podamos ver más allá de lo que realmente está ocurriendo.

Este estudio se centra en dos vertientes, por una lado la tafonómica, a través de la experimentación, con el objetivo de crear sólidos criterios que permitan distinguir a través de las marcas de corte halladas en las epífisis y metadiáfisis de los huesos largos (habitualmente son las partes óseas mejor conservadas), qué tipo de actividades, bien descarnado o desarticulado, eran realizadas por los seres humanos y de qué manera o qué herramientas resultaban más efectivas para dichas tareas. Hasta el momento, tan sólo dos estudios se han centrado en esta cuestión, Binford (1981) y Nilssen (2000). En el primero, los experimentos se realizaron sin ningún tipo de control y con cuchillos de metal, y en el caso del segundo, aunque se estableció un exhaustivo control en los experimentos, fue realizado en su totalidad con herramientas de metal. Estos motivos cuestionan su fiabilidad si queremos crear marcos referenciales que sean aplicados a contextos prehistóricos.

Así, surge la necesidad de crear dichos marcos referenciales bajo rigor absoluto, cómo es la utilización de herramientas líticas que nos permitan establecer patrones con el objetivo de discernir las actividades de aprovechamiento de los recursos animales.

Por otro lado, también se va a basar en un estudio osteométrico, con el objetivo de sexar individuos, debido a que sabemos que algunos carnívoros depredan sobre edades y sexos determinados en función de una presa u otra, por lo que el objetivo es conocer si el ser humano también muestra algún tipo de preferencia a la hora de acceder a los recursos cárnicos.

Por ello, los objetivos principales de esta tesis son los siguientes:

- Elaboración de un mapa anatómico en la distribución anatómica de marcas de descarnado y desarticulado.
- Creación de un protocolo para diferenciar marcas de descarnado y desarticulado en las epífisis y metadiáfisis de los huesos largos.
- Comprobar cuál de los tres sets de herramientas empleados es más eficaz para las diferentes actividades en el procesado de carcasas animales (desollado, descarnado, desarticulado).
- Verificar que set de herramientas es más eficaz en términos de materia prima empleada.

- Comprobar si existe relación entre la amplitud del filo y la masa de la herramienta con la eficiencia en el proceso.
- Distinción del sexo en bóvidos africanos a través de determinadas medidas tomadas en pelvis.
- Mejorar el marco referencial con el que interpretar los conjuntos faunísticos pleistocénicos, con el objeto de interpretar la subsistencia durante el Paleolítico.

En síntesis, es posible la distinción entre la distribución de marcas de descarnado y desarticulado, ya que ambos tipos de marcas se concentran en diferentes áreas. Por ejemplo, en el caso de la tibia, las marcas de descarnado se agrupan principalmente en la parte lateral de la metadiáfisis proximal, mientras que las de desarticulado lo hacen en los lados caudal y lateral de la metadiáfisis proximal, el maléolo medial y sobre el mismo y la parte inferior de la diáfisis. Las herramientas que mayor número de marcas de desarticulado producen son los bifaces, en contraste con las lascas retocadas que producen un mayor número de marcas de descarnado.

En cuanto a la eficacia de bifaces, lascas simples y retocadas, principalmente destacar que los bifaces son las herramientas más eficientes para el descarnado de una carcasa animal. Además, podemos decir que las marcas de corte generadas por los tres conjuntos de herramientas no se producen de forma arbitraria, al contrario, generan patrones que pueden ser demostrables estadísticamente.

Respecto a la diferenciación de sexos en bóvidos, son determinadas medidas en el acetábulo de la pelvis, por ser éste una de las partes más sensibles para determinar el sexo, las que hacen posible una separación por sexos, especialmente la medida de la pared medial del acetábulo, independientemente de la especie y la talla del animal.

Tras la realización de este trabajo y en conclusión, principalmente podemos afirmar que se ha logrado la creación de un mapa anatómico para la diferenciación de marcas de descarnado y desarticulado en huesos largos; que los bifaces son las herramientas más eficaces en términos de inversión de tiempo para procesar una carcasa; que las marcas de corte generadas no se producen al azar y la creación de una metodología para discernir el sexo en bóvidos sin tener en cuenta el taxón al que se aplica.

SUMMARY

The criteria we find today to reconstruct certain activities of subsistence performed by humans on animal carcasses acquired in hunting activities are not enough to know with the greatest certainty

what behaviours were displayed during butchery. The mail objective of this research is to address this question.

The present work is focused on two aspects, on the one hand, taphonomic, through the experimentation, with the aim to create solid criteria for distinguishing the cut marks found on the epiphysis and metadiaphysis of the long bones, what activities, either defleshing or disarticulation, were performed by humans and how or what stone tools were more effective for these activities. Up to now, only two studies have focused on this question, Binford (1981) and Nilssen (2000). In the first case, the experiments were carried out without control and using metal knives. In the second case, there was a severe control but it was totally performed using metal tools. For this reason, we question their reliability if we want to create referential frameworks to apply in prehistoric contexts.

Thus, it was necessary to create referential frameworks under more rigor, experimentally developing the use of stone tools, which would allow us to establish new patterns with the aim of discerning among exploitation activities.

On the other hand, an osteometric study, with the objective to identify sex in bovids, because we know that some carnivores prey on certain sexes and ages, depending on the prey. For this reason, we want to know if the humans show some kind of preferences when they access meat resources.

Therefore, the main objectives of this thesis are:

- Development of an anatomical map for the distribution of defleshing and disarticulation cut marks.
- Creating a protocol to distinguish between defleshing and disarticualation cut marks.
- Testing which of three generic stone tool sets employed is more efficient for skinning, defleshing and disarticulation.
- Checking which of the three stone tool sets is more efficient in terms of raw material use.
- Testing if there is a relationship between the length of the edge and stone tool mass with the efficiency of the process.
- Distinguishing the sex of African bovids through certain measurements from the pelvis.
- Improving the referential framework to explain the Pleistocenic faunal remains with the aim of improving our knowledge of the subsistence along the Paleolithic.

In short, it is possible the distinction between defleshing and disarticulation cut marks, because both types of marks are found on different areas. For example, in the case of the tibia, defleshing cut marks are mainly grouped on the lateral face of the proximal metadiaphysis, while disarticulation cut marks are distributed on lateral and caudal sides of proximal metadiaphysis, on the medial maleolus and above it and in the lower area of the shaft. The stone tools which produce more number of disarticulation cut marks are handaxes, in contrast with retouched flakes, which provide a higher number of defleshing cut marks.

Regarding to the efficient of handaxes, simple and retouched flakes, we have to emphasize that handaxes are the most efficient stone tools for defleshing an animal. Furthermore, we can say that the cut marks produced by the three stone toolkits do not occur randomly. On the contrary, they show patters statistically demonstrable.

In relation to the differentiation of the sex in bovids, there are certain measurements in the pelvis acetabulae which make possible to separate both sexes, specially the measurement of the medial acetabular wall, independently of the species and the size of the animal.

INTRODUCCIÓN

Tras haber centrado mis primeras investigaciones en el ámbito tafonómico, estableciendo protocolos para la discriminación de marcas de percusión realizadas con percutor modificado y no modificado, la rotura de huesos por parte de carnívoros y por percusión así como el establecimiento de características diagnósticas de las marcas de percusión (Galán *et al.* 2009); la diferenciación de marcas de corte de las marcas de trampling a través de determinados rasgos diagnósticos (Domínguez-Rodrigo *et al.* 2009); y el establecimiento de criterios para discernir entre marcas de corte realizadas con bifaces y lascas simples y retocadas (De Juana *et al.* 2010), esta tesis doctoral nace con la motivación de dar respuesta a aquellas cuestiones aún confusas y que impiden una mejor reconstrucción de determinadas actividades de subsistencia llevadas a cabo por los seres humanos a través de la adquisición de carcasas mediante actividades cinegéticas.

El presente estudio se ha centrado en dos líneas de investigación desarrolladas en tres artículos. Las dos primeras desde un enfoque tafonómico, a través de la experimentación, centradas en discernir las marcas de desarticulado y descarnado en los extremos de las epífisis y comprobar la eficacia de tres tipos diferentes de herramientas de piedra. Por otro lado, la tercera, con un enfoque osteométrico. Ambas líneas están destinadas a la reconstrucción de estrategias de subsistencia.

Aunque las características de las marcas de corte y los criterios para distinguirlas de otro tipo de marcas han sido descritos por diversos autores (Guilday *et al*. 1962; Walker and Long, 1977; Bunn, 1981; Potts and Shipman, 1981; Shipman, 1983; Cook, 1986; Lyman, 1987; Milo, 1994; Fisher, 1995; Greenfield, 1999; Bello y Soligo, 2008, Domínguez-Rodrigo *et al*. 2009), distinguir las marcas de descarnado y desarticulado en los extremos de la epífisis ha sido siempre una tarea problemática. Hasta el momento sólo teníamos dos trabajos que abordasen esta cuestión. El primero de ellos llevado a cabo por Binford (1981), realizado de forma no controlada y en el cual se establecía un mapa anatómico con la localización de las marcas de corte en función de la actividad realizada (desollado, descarnado y desarticulado). El segundo, realizado por Nilssen (2000) y bajo un protocolo de control, ofrece una nueva localización de las marcas de corte en los extremos de las epífisis con algunas discrepancias sobre el trabajo de Binford (1981). Sin embargo, ambos estudios incurren en el mismo error: fueron realizados empleando navajas de metal en lugar de herramientas de piedra, por lo que no son una referencia real que pueda ser aplicada a contextos paleolíticos.

Unido a esto, también hemos sometido a experimentación la eficacia de tres sets de herramientas de piedra divididas en tres grandes grupos: lascas simples, bifaces y lascas retocadas. Para ello nos basamos en la tasa de retorno, es decir, el balance entre energía y/o tiempo invertido durante el procesamiento de una carcasa y las calorías obtenidas en el mismo. Aunque algunos estudios de tasas de retorno han sido aplicados al Pleistoceno (Lupo, 1998; Madrigal y Holt, 2002; Marean y Cleghorn, 2003) no siempre han producido resultados satisfactorios, proporcionando interpretaciones contradictorias para los procesos de carnicería (Lupo, 1998; Madrigal y Blumenschine, 2000). Del mismo modo, no ha sido encontrada correlación entre las tasas de retorno y el transporte de hueso en experimentos llevados a cabo en lugares etnográficos actuales (Marean y Cleghorn, 2003), debido a, posiblemente, no tener en cuenta los sesgos tafonómicos (Egeland y Byerly, 2005). Son las tasas de retorno compuestas, es decir, aquellas calculadas teniendo en cuenta los costes asociados a la extracción de médula y el descarnado, las más adecuadas para abordar las decisiones de procesado de carcasas en lugar de su transporte a un sitio determinado (Egeland y Byerly, 2005).

Tomando como referencia los estudios de tasas de retorno, en este trabajo se aborda la eficiencia de lascas simples, retocadas y bifaces. Las interpretaciones de éstas y sus ventajas adaptativas han sido objeto de debate en la literatura, como es el caso de las lascas simples, consideradas las herramientas de piedra más eficientes (Schick y Toth, 1993). Las huellas de uso muestran que las lascas retocadas eran ampliamente utilizadas durante el Musteriense para actividades de raspados de cuero, trabajo de madera y descarnado (Beyries, 1987,1988; Keeley, 1980). También existe la evidencia de fitolitos en el Pleistoceno inferior hallados en bifaces que lo relacionan con el trabajo de madera (Domínguez-Rodrigo *et al*. 2001) y evidencias microscópicas de su uso para actividades de carnicería en el Pleistoceno Medio (Keeley, 1980; Mitchell, 1997, 1998; Ollé, 2005; Ollé *et al*. 2010). Del mismo modo, trabajos experimentales y descriptivos como el de Jones (1980) sugieren que son más efectivas las lascas simples que las retocadas. Sin embargo, esta asunción se basaba en experiencias personales del carnicero y no en la toma de medidas de control de tiempo. Mitchell (1996) va un paso más allá documentando, aunque de forma insuficiente, que los bifaces son más útiles que las lascas simples, algo totalmente opuesto a lo que se pensaba hasta ahora.

La reconstrucción de estrategias de subsistencia no sólo es posible abordarla desde un punto de vista tafonómico, también podemos reconstruir patrones de caza a través del sexado de las carcasas encontradas en los yacimientos (Weinstock, 2000; Arceredillo *et al*. 2011; Greenfield, 2002; Munro *et al*. 2011; Davis, 2012). A pesar de su importancia, la cuestión del sexado se ha visto habitualmente relegada a un segundo plano en la literatura debido posiblemente a su naturaleza fragmentaria (Klein y Cruz-Uribe, 1984; Munro *et al*. 2011) en la que en muchas ocasiones se encuentran los restos faunísticos en los yacimientos, especialmente en contextos como los del Paleolítico.

Tradicionalmente, el sexado ha sido abordado desde enfoques Neolíticos (Greenfield, 2002; Munro *et al*. 2011), protohistóricos o históricos (Davis, 2012), centrándose la mayor parte de las aplicaciones prácticas de estos estudios en animales domesticados (Berteaux y Guintard, 1995; Telldahl *et al*. 2012; Davis, 2012; Greenfield, 2002), siendo menos habituales en la literatura aquellos estudios que aplican técnicas de sexado al Paleolítico (Arceredillo *et al*. 2011; Weinstock, 2000). Sin embargo, la mayor parte de estos estudios poseen un común denominador: la metodología que desarrollan se centra en una única especie, habitualmente la más común en el yacimiento para el que aplican su estudio (Berteaux y Guintard, 1995; Telldahl *et al*. 2012; Davis, 2012; Arceredillo *et al*. 2011; Weinstock, 2000; Munro *et al*. 2011), dejando de lado metodologías estandarizadas que abarquen un mayor rango de especies.

La forma más común y tradicional de sexar ha sido a través de características morfológicas o rasgos diagnósticos como el tipo de cornamentas en cérvidos y bóvidos, la presencia o ausencia de caninos en équidos y suidos, el hueso del pene en los carnívoros o la forma de la pelvis (Klein y Cruz-Uribe, 1984; Greenfield, 2002; Munro *et al*. 2011). No obstante, existen diversas formas para sexar: a través de las medidas de determinadas partes esqueléticas (Greenfield, 2002; Munro *et al*. 2011; Berteaux y Guintard, 1995; Telldahl *et al*. 2012; Davis, 2012; Arceredillo *et al*. 2011; Weinstock, 2000) o teniendo en cuenta determinados rasgos característicos en algunas partes esqueléticas (Munro *et al*. 2011).

El objetivo cuando queremos separar sexos en conjuntos óseos del Paleolítico es poder determinar si existe algún tipo de preferencia por parte de los homínidos a la hora de depredar sobre un sexo u otro. Este comportamiento ya es observado en la naturaleza por parte de algunos carnívoros. La hiena moteada muestra una fuerte preferencia por los machos en el caso del ñu, tanto en el Ngorongoro como en el Serengeti y por las hembras en el caso de las cebras también en ambos lugares (Kruuk, 1974), mostrando que son selectivos cazadores ya que no sólo tienen preferencias sobre unas especies u otras sino que también seleccionan individuos dentro de cada especie (Kruuk, 1974). Los leones también depredan con mayor frecuencia sobre ñus machos en el Serengeti, mientras que en el caso de las cebras acceden a ambos sexos por igual, excepto en aquellos individuos más ancianos, predando en este caso un mayor número de machos (Schaller, 1974). En el Serengeti los leopardos cazan principalmente machos de gacela Thomson, y hembras en el caso de la redunca (Schaller, 1974), mientras que en el Kalahari seleccionan mayoritariamente hembras de gacela Thomson (Mills, 1990). Los guepardos muestran una caza equitativa de ambos sexos de gacela Thomson en el Serengeti (Schaller, 1974), aunque predan más sobre hembras en aquellos individuos más ancianos. Sin embargo, en el Kalahari la tendencia cambia, cazando con más frecuencia gacelas Thomson macho (Mills, 1990). Este tipo de comportamientos selectivos se ven condicionados por diversos factores, como son la vulnerabilidad de la presa en un sexo u otro, como es el caso del ñu, siendo los machos más vulnerables que las hembras a la malnutrición y las enfermedades, o de las cebras, más vulnerables las hembras ante el proceso reproductivo y al hecho de que los machos permanecen en grupos (Schaller, 1974).

Arceredillo *et al*. (2011) observan la preferencia de los grupos de Neandertales que habitaron el sitio de Valdegoba (Burgos) sobre machos de gamuza (*Rupicapra rupicapra*).

OBJETIVOS DEL ESTUDIO

Los objetivos del presente estudio son los siguientes:

- Creación de un protocolo que permita distinguir de forma inequívoca las marcas de descarnado de las de desarticulado en las epífisis y metadiáfisis de los huesos.
- Realizar un mapa de distribución anatómica de las marcas de corte en las epífisis para las actividades de descarnado y desarticulado.
- Someter a contrastación cuál de los tres sets de herramientas de piedras empleados en los experimentos es más efectivo para desollar, descarnar y desarticular carcasas animales y comprobar si generan los mismos patrones de marcas de corte.
- Testar cual de los tres tipos de herramientas de piedra empleadas es más eficaz en términos de materia prima empleada.
- Comprobar si existe relación entre la amplitud del filo y la masa de la herramienta con la eficiencia en el proceso.
- Proporcionar un nuevo método para discernir el sexo en bóvidos a través de determinadas medidas en el acetábulo de la pelvis.
- El objetivo final es mejorar el marco referencial con el que interpretar los conjuntos faunísticos pleistocénicos, con el objeto de interpretar la subsistencia durante el paleolítico.

MATERIAL Y MÉTODOS

Para los dos primeros artículos fueron empleados un total de 6 ciervos (*Cervus elaphus*) cuyo peso oscilaba entre los 60 y 70 Kg y adquiridos todos ellos en monterías legales. Fueron llevados a cabo tres tipos de experimentos según el tipo de herramienta empleado: lascas simples, lascas retocadas y bifaces. Para cada uno de ellos se procesaron completamente dos carcasas.

Figura 1. Lascas simples, retocadas y bifaces que fueron empleadas en el experimento.

Los seis animales fueron procesados por un cazador experto, cuya experiencia asciende a más de 30 años. Tanto el descarnado como la desarticulación fueron llevados a cabo con el animal totalmente tendido en el suelo. Excepto para la eventración, donde se empleó una navaja de metal y para facilitar el transporte de las carcasas, los experimentos fueron llevados a cabo con herramientas de piedra (incluido el desollado) siguiendo el siguiente protocolo: primero en el descarnado, al llegar los extremos las marcas realizadas eran perpendiculares al eje del hueso, mientras que las de desarticulado se hacían al llegar a las epífisis oblicuas al eje del hueso.

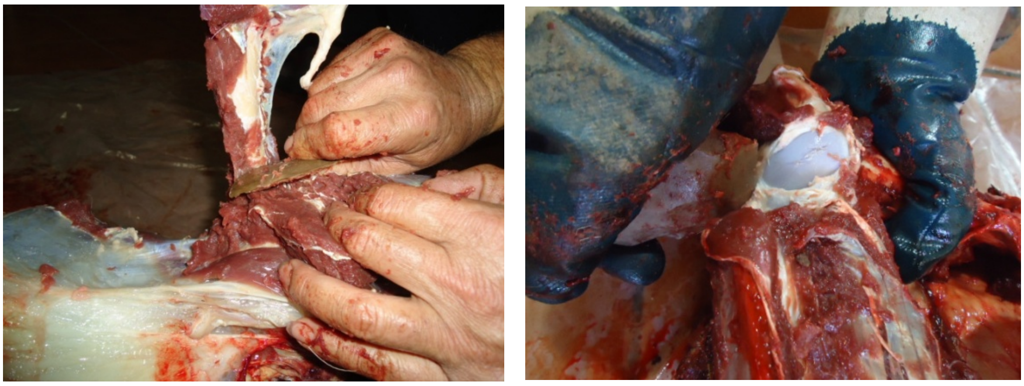


Figura 2. Descarnado (izquierda)/Desarticulado (derecha)

Aplicando un estricto control, el proceso fue grabado en video, como en el caso de Nilssen (2000) y fotografiado, y cada actividad realizada en cada hueso fue cronometrada para poder comprobar la eficiencia de cada herramienta de piedra. En total fueron empleadas nueve lascas simples, siete lascas retocadas y tres bifaces. Las lascas retocadas y simples fueron realizadas por un tallador experto y los bifaces era réplicas funcionales. Para la limpieza de los huesos, estuvieron enterrados durante seis meses, para después ser limpiados con agua y eliminar el sedimento adherido.

Para el primer artículo las marcas de corte fueron aisladas en las metadiáfisis y epífisis de los huesos, con excepción de la parte distal del radio y de la tibia. Las marcas fueron identificadas a ojo utilizando una lupa de mano de 15x. Una vez que todas las marcas fueron localizadas en cada hueso, se representaron en plantillas (Figura 3) de cada hueso empleado el programa Adobe PhotoshopCS4.

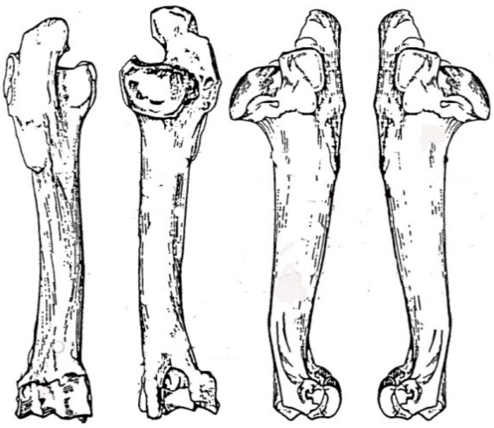


Figura3. Plantillas para localización marcas de corte.

En las imágenes, las marcas de desarticulado fueron representadas con líneas oblicuas rojas y las de descarnado con líneas verdes perpendiculares. Las marcas de desollado sobre metacarpos y metatarsos fueron representadas en color azul.

En el caso del segundo artículo, con el objetivo de verificar si la distribución de marcas de corte seguía un patrón, cada hueso fue dividido en cinco secciones: epífisis proximal, metadiáfisis proximal, diáfisis, metadiáfisis distal y epífisis distal y las marcas fueron agrupadas lado (craneal, caudal, medial y lateral) y sección (Yravedra y Domínguez-Rodrigo, 2009). Todas estas marcas fueron representadas en plantillas de cada hueso usando el programa Adobe Photoshop CS5.

Los análisis estadísticos se realizaron con el programa R (www.r-project.org). En el primer artículo, para comparar si los tres sets experimentales poseían una cantidad similar de marcas de corte fueron empleados tests ANOVA. Para el segundo artículo, primero se realizaron análisis de varianza, como el test de Bartlett, el test de Kruskal Wallis y test de Wilcoxon pairwise. Después, empleando el programa R fueron realizadas correlaciones llevadas a cabo a través de método no paramétrico de Spearman usando una regresión robusta (“rlm” R function), además de una regresión múltiple comparando simultáneamente como la amplitud del filo y el peso podrían estar correlacionados con el tiempo de procesado de acuerdo al tipo de herramientas. También fue llevado a cabo un Análisis de Componentes Principales usando el "FactoMineR". Las frecuencias de marcas de corte fueron comparadas con los test de Kruskal Wallis y chi-cuadrada. Para analizar la distribución de marcas de corte se empleó el Test Multinomial Exacto (EMT), prueba de bondad de ajuste para datos discretos. El EMT proporciona una estimación de la probabilidad que evalúa si en un vector se producen patrones o al azar, bajo el supuesto de un modelo ab initio.

Para el tercer artículo fueron incluidos bóvidos africanos. Aunque el objetivo inicial era la obtención de las medidas de más de cincuenta especies, finalmente se redujo a ocho, debido a que en algunas ocasiones los especímenes eran inmaduros, por lo que quedaban excluidos del estudio o no se encontraban sexados (Greenfield, 2002). El resultado final fue una muestra compuesta por 109 individuos y 172 acetábulos. Las especies incluidas en el estudio fueron las siguientes: *Gazella dorcas* (gacela dorcas), *Gazella granti* (Gacela Grant), *Alcelaphus buselaphus* (alcelafo), *Tragelaphus strepsiceros* (Gran Kudú), *Taurotragus oryx* (eland común), *Tragelaphus scriptus* (bosbok), *Aepycerus melampus* (impala), *Kobus ellipsiprymnus* (antílope acuático).

Todas las medidas fueron tomadas de las colecciones de zoología de los museos de Historia Natural de Londres y Paris. Para ello fue empleado un calibre digital para una mayor precisión y cada medida introducida en una base de datos.

Siguiendo los trabajos de Greenfield (2002) y Von den Driesh (1976) fueron tomadas ocho medidas por cada acetábulo. Son descritas brevemente a continuación:

- H1: mide el grosor de la pared medial del acetábulo (Greenfield, 2002).
- H2: mide la altura de la pared del acetábulo (Greenfield, 2002).
- LA: mide la longitud del acetábulo por su parte lateral incluyendo el labio (Von den Driesch,1976; Greenfield, 2002).
- LAR: mide la longitud interna del acetábulo por la cara lateral (Von den Driesch,1976; Greenfield, 2002).
- WA (Greenfield, 2002) W2 (propuesta por los autores): mide el ancho del acetábulo y es tomada desde el borde del acetábulo hacia la incisura acetabular. Para acetábulos abiertos son tomadas las dos medidas, para acetábulos cerrados únicamente W2.

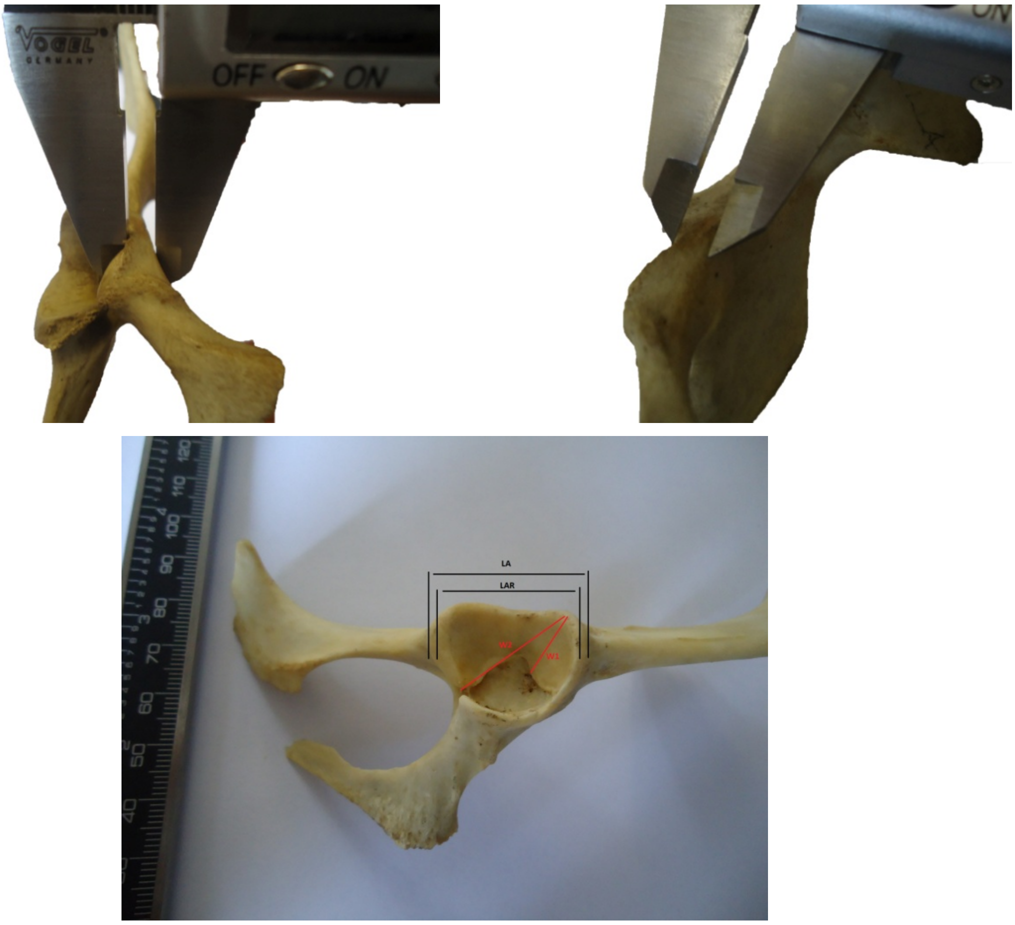


Figura 4: Toma de medidas de H1 (superior izquierda), H2 (superior derecha) y LA, LAR, WA y W2 (inferior).

Además de W2, dos medidas más son propuestas para el estudio:

- LA2: mide la longitud externa de acetábulo, incluyendo el labio, por el lado medial.
- LAR2: mide la longitud interna del acetábulo y es tomada desde la cara medial del mismo.

Figura 5: Toma de medidas de LA2 y LAR2.

Al igual que en los trabajos anteriores, los análisis estadísticos se realizaron usando el programa R (www.r-project.org), a través del Análisis de Componentes Principales (ACP), escalando las variables en un análisis preliminar. Debido a la amplitud de la parte de varianza de la muestra explicada, fueron seleccionados dos componentes de solución. Una vez que las variables que mejor determinaban el sexo fueron identificadas, se llevó a cabo una regresión logística (RL) para determinar el ratio de aquellas variables que discriminaban entre macho y hembra a través de la morfología del acetábulo.

RESUMEN DE LOS ARTÍCULOS

I. Galán, A.B., Domínguez-Rodrigo, M. 2013. An experimental study of the anatomical distribution of cut marks created by filleting and disarticulation on long bone ends. *Archaeometry,* **55**, 6*.* 1132-1149.

En este artículo se compara y contrastan las marcas de corte de descarnado y desarticulado generadas en los experimentos de Binford (1981) y Nilssen (2002) con el experimento realizado para el presente estudio. Además se crea un mapa con la localización anatómica de dichas marcas con el propósito de poder ser distinguidas en función del tipo de herramienta empleada.

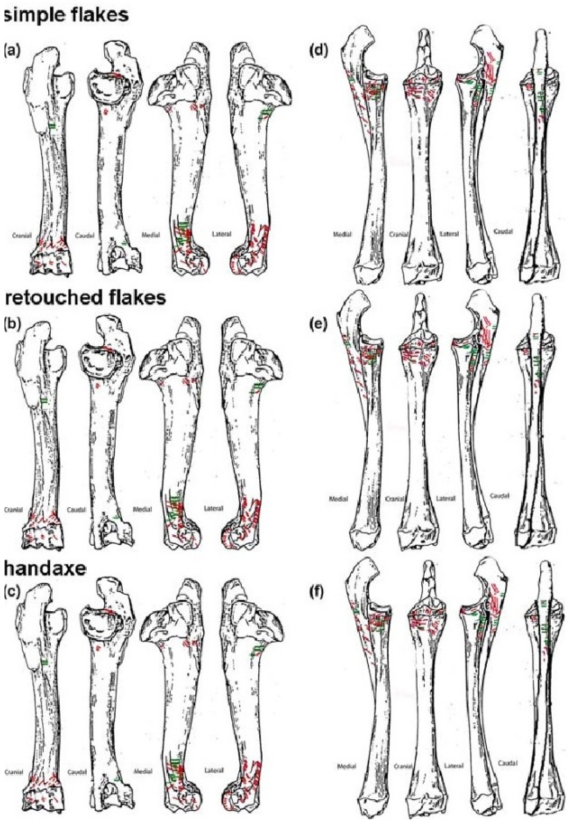
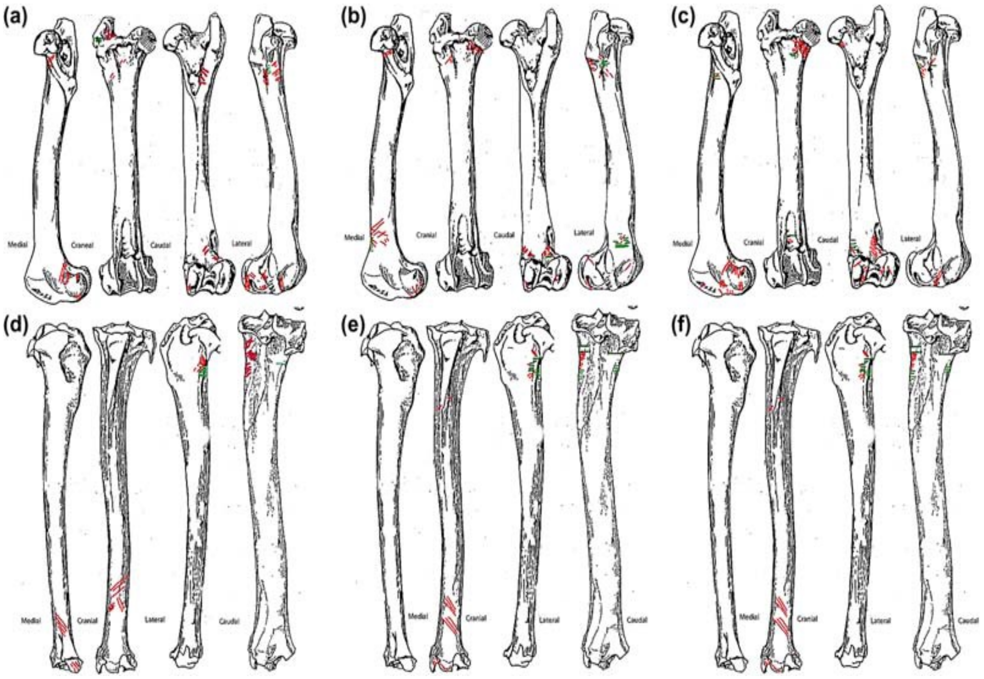


Figura 6. Distribución de marcas de descarnado y desarticulado en húmero (izquierda) y radio-ulna (derecha).

Los resultados muestran en el caso del húmero (Figura. 6) comparando los tres sets de herramientas como las marcas tanto de desarticulado como descarnado se concentran en la epífisis y metadiáfisis distal, en lados craneal, medial y lateral, siendo menos frecuentes en la epífisis proximal. La principal diferencia en la localización para las marcas de corte de desarticulado se localiza en el lado cauda de la epífisis distal, donde sí se dan marcas de descarnado.

Para el radio (Figura.6), de acuerdo a los tres tipos de experimentos podemos observar como las marcas de descarnado y desarticulado se localizan en las mismas áreas: en la epífisis proximal en los lados craneal, cauda y medial. En el caso de la ulna ambos tipos de marcas aparecen en los lados medial, caudal y lateral excepto para la muestra realizada con bifaces, para la que no se identifican marcas de desarticulación en el lado caudal.



Figuras 7. Distribución de marcas de descarnado y desarticulado en fémur (arriba) y tibia (abajo).

En el fémur (Figura 7), al comparar los experimentos con los tres sets de herramientas se observa como las marcas de desarticulación en la epífisis proximal se distribuyen principalmente en el cuello y bajo el trocánter mayor. En la epífisis distal estas marcas se localizan en los cóndilos y epicóndilos lateral y medial. En cuanto a las marcas de descarnado, con lascas retocadas las marcas de corte son documentadas en el trocánter mayor y la cresta trocantérica, con lascas retocadas sin embargo bajo el trocánter mayor con superposición con las marcas de desarticulado. En la epífisis distal se localizan en el cóndilo lateral, también superponíendose a las marcas de desarticulado y el metadiáfisis distal (caral medial y lateral). Al emplear bifaces las marcas de descarnado se concentran en la metadíafisis proximal, en lados craneal, medial y lateral, mientras que en la zona distal se distribuyen sobre la tróclea (vista craneal) y sobre el cóndilo medial (cara caudal).

En la tibia (Figura 7) se observan varias áreas comunes en el caso de las marcas de desarticulado: la metadiáfisis proximal en lados lateral y caudal, el maléolo medial y la zona sobre el mismo y la parte más baja de la diáfisis, mientras que las marcas de descarnado se agrupan en el lado lateral de la metadiáfisis proximal.

En metacarpos y metatarsos (Figura 8) las marcas documentadas corresponden únicamente al desarticulado y el desollado, agrupándose las primeras en la epífisis proximal y las segundas en la parte alta de la diáfisis. En los cárpales y tarsales todas las marcas observadas corresponden a la desarticulación.

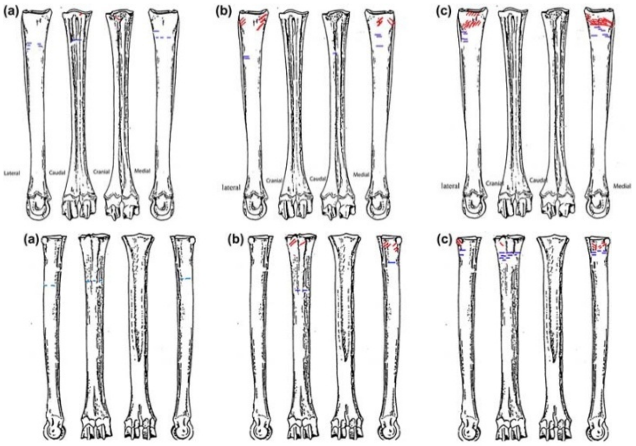
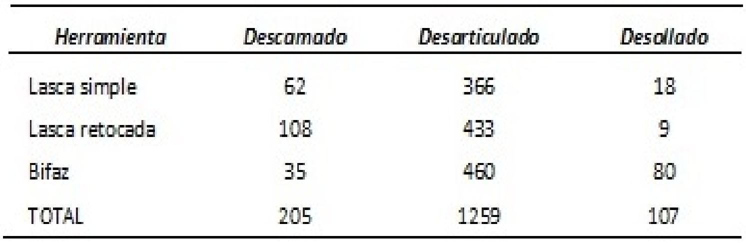


Figura 8. Distribución de marcas de corte de descarnado y desarticulado. Metatarso (Arriba), metacarpo (abajo).

Finalmente, si consideramos en número de marcas según la actividad llevada a cabo, las marcas de desarticulado aparecen con una frecuencia ligeramente mayor a las de descarnado (Tabla 1).



Herramienta	*Descamado*	*Desarticulado*	*Desollado*
Lasca simple	62	366	18
Lasca retocada	108	433	9
Bifaz	35	460	80
TOTAL	205	1259	107

Tabla 1. Número marcas de cote según herramienta y actividad

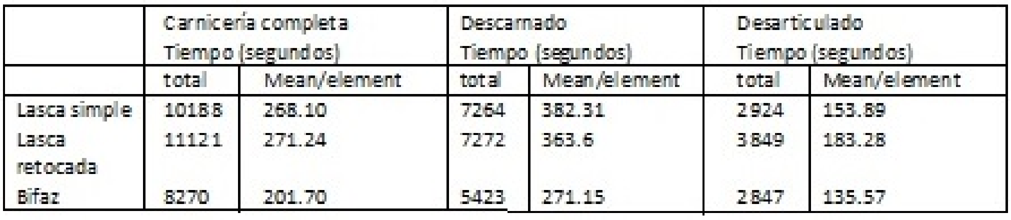
Al considerar el número de marcas según el tipo de herramienta empleada se observa como los bifaces producen más marcas de desarticulación y desollado que otras herramientas y el número más bajo de marcas de descarnado. Las lascas simples producen el número más bajo de marcas de desarticulado mientras que las lascas retocados producen el mayor número de marcas de descarnado. Según el tipo de hueso las marcas de descarnado son más abundantes en el radio, seguidas del húmero, el fémur y la tibia.

II. Galán, A.B., Domínguez-Rodrigo, M. 2014. Testing the efficiency of simple flakes, retouched flakes and small handaxes during butchery. *Archaeometry,* **56***,* 6. 1054-1074.

Este trabajo analiza aquellas cuestiones relacionadas con la eficacia de bifaces, lascas simples y retocadas en diversas actividades de carnicería, como son el tiempo de procesado, la frecuencia de las marcas de corte, la influencia de la longitud del filo y la masa de la materia prima en su eficacia y la existencia o no de patrones de las marcas de corte.

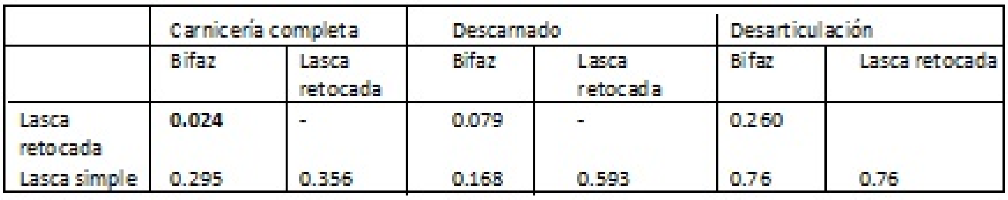
Tiempo de procesado

El test de Kruskal Wallis muestra diferencias significativas en el tiempo de procesado para cada set herramientas (chi-cuadrado = 6.78, p = 0.0337) (Tabla 2), siendo los bifaces las herramientas más eficientes a la hora de procesar una carcasa. Analizando los datos en función de la actividad realizada, para descarnar son claramente más eficientes los bifaces mientras que en el caso de la desarticulación, las diferencias entre los tres conjuntos de herramientas son poco significativas (Tablas 2 y 3).



	Carnicería completa Tiempo (segundos)		Descarnado Tiempo (segundos)		Desarticulado Tiempo (segundos)	
	total	Mean/element	total	Mean/element	total	Mean/element
Lasca simple	10188	268.10	7264	382.31	2924	153.89
Lasca retocada	11121	271.24	7272	363.6	3849	183.28
Bifaz	8270	201.70	5423	271.15	2847	135.57

Tabla 2. Tiempo empleado según actividad y herramienta.



	Carnicería completa		Descarnado		Desarticulación	
	Bifaz	Lasca retocada	Bifaz	Lasca retocada	Bifaz	Lasca retocada
Lasca retocada	**0.024**	-	0.079	-	0.260	
Lasca simple	0.295	0.356	0.168	0.593	0.76	0.76

Tabla 3. El test de Wilcoxon pairwise muestra el valor de probabilidad con similar promedio de tiempo entre pares de conjuntos de herramientas. Diferencias significativas en negrita.

Longitud del filo y masa de la materia prima

En cuanto a la longitud de los filos, la hipótesis nula de la existencia de la misma longitud en los filos para los tres conjuntos de herramientas es rechazada por el test de Kruskal Wallis (chi-cuadrado = 7.3402, p = 0.0254). Por ello, para el procesado de una carcasa con lascas simples se requiere la mayor longitud de filo mientras que con un bifaz la menor de todas ellas (Tabla 3).

Respecto a la masa de la materia prima, el test de Kruskal Wallis muestra diferencias significativas entre los tres tipos se conjuntos (chi-cuadrado = 7.8004, p = 0.020). En términos de eficiencia, existe una importante correlación entre la longitud del filo y el tiempo de procesado para las lascas retocadas (Rho=0.928, p= 0.006), mientras que con bifaces y lascas simples esta correlación no es significativa (p=>0.05). El análisis de regresión múltiple muestra que el tiempo de procesado no se ve afectado por el perímetro y el peso de la herramientas cuanto son considerados en conjunto (R2= 0.16; p=>0.05).

Por ello, si consideramos la eficiencia como la maximización del procesado de una carcasa invirtiendo la menor cantidad de materia prima, en este caso son las lascas simples y retocadas más eficientes para actividades de carnicería que los bifaces (Tabla 2).

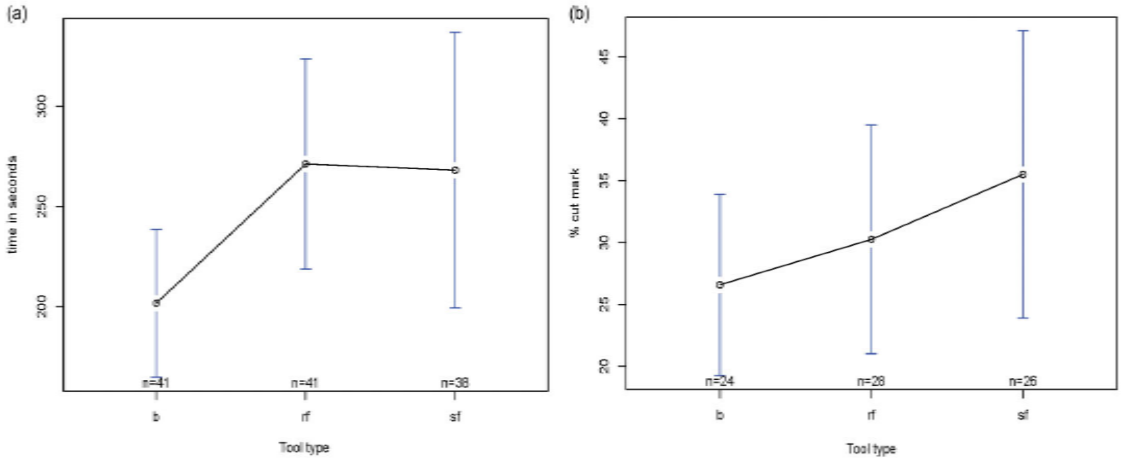
Frecuencias de las marcas de corte

Según el test de Kruskal Wallis, las diferencias en las frecuencias de las marcas de corte al comparar los tres tipos de herramientas no son significativas (chi-cuadrado = 0.447, p = 0.799). La misma conclusión es obtenida al aplicar el test de la chi-cuadrado (chi-cuadrado = 1.706, p = 0.999).

Patrones de las marcas de corte

Los tests multinomiales (EMT) muestran patrones anatómicos distinguibles y estadísticamente detectables en la distribución de frecuencias de marcas de corte (Tablas 3 y 4). En todos los huesos se observa un patrón en la localización de las marcas de corte (p<0.05), el cual se encuentra condicionado por la alta concentración de marcas de corte en las diáfisis comparadas con las secciones de la metadiáfisis y epífisis (Tabla 3). Esto mismo es observado al aplicar los tests multinomiales en las secciones de las diáfisis de forma aislada, mostrando que las marcas de corte no se producen aleatoriamente.

Por lo tanto, la existencia de patrones en todos los huesos y secciones sugiere que cualesquiera que sean las razones que lo explican, ya sean ergonómicas o de la disposición de las inserciones musculares o una combinación de ambas, la distribución de marcas de corte en los huesos largos no se produce al alzar y es un proceso completamente estocástico (Figuras 10 y 11).



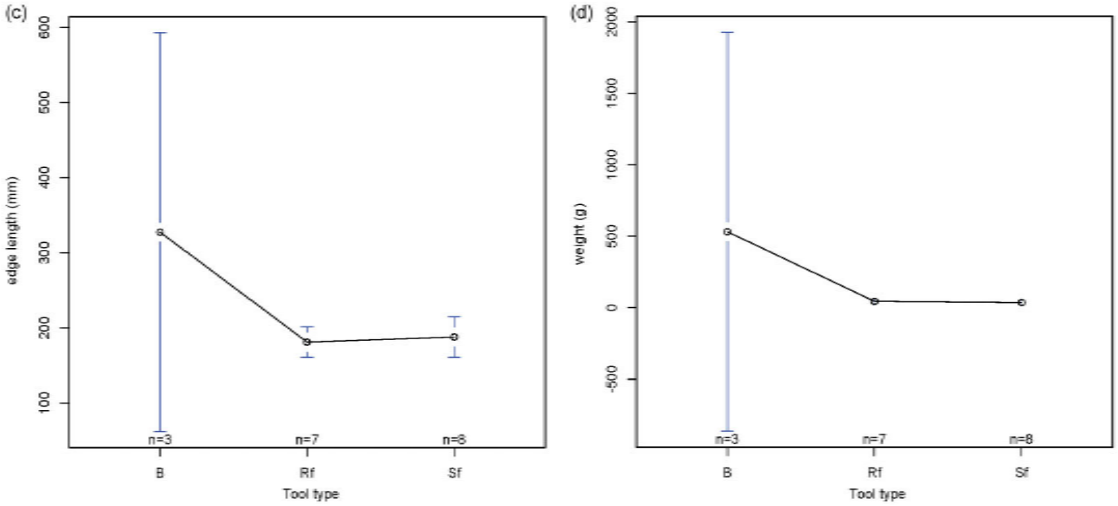


Figura 10. Valores y 95% de intervalos de confianza para cada tipo de herramienta: a) tiempo de procesado; b) frecuencias de las marcas de corte; c) longitud del filo; d) peso de la herramienta.

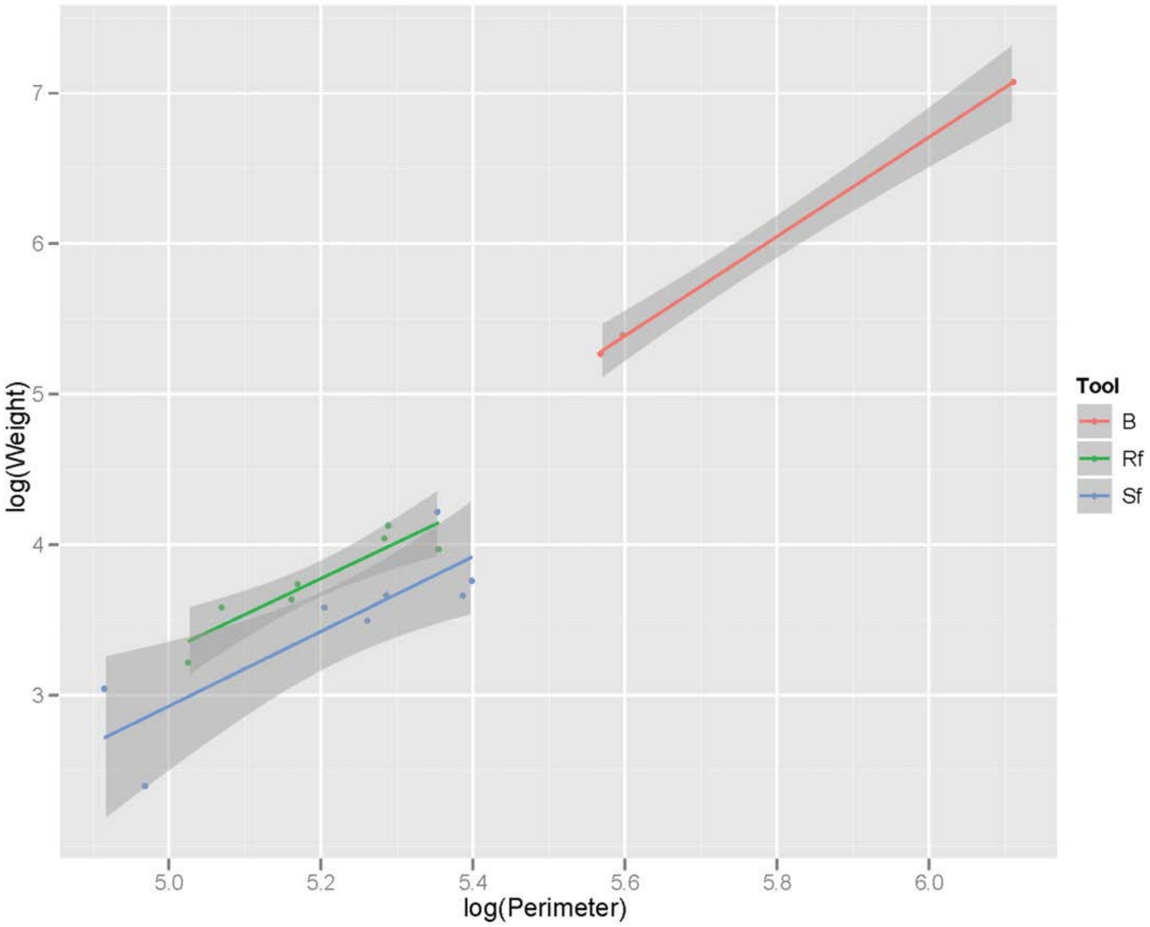


Figura 11. Regresión lineal de log (peso) y log (perímetro del filo) para cada tipo de herramienta usada.

III. Galán, A.B., Domínguez-Rodrigo, M. 2014. A biometric analysis of the pelvic acetabulum as an indicator of sex in bovids. *C.R. Palevol*, **13**, 561-567.

La identificación de individuos en función del sexo en los conjuntos faunísticos juega un importante papel en la reconstrucción de estrategias de caza y patrones de subsistencia prehistóricos (Weinstock, 2000; Arceredillo *et al*. 2011; Greenfield, 2002; Munro *et al*. 2011; Davis, 2012).

El sexado es posible gracias a determinadas características morfológicas como son la cornamenta en cérvidos y bóvidos, la presencia o ausencia de caninos en équidos, el hueso del pene en los carnívoros o la forma de la pelvis (Klein y Cruz-Uribe, 1984; Greenfield, 2002; Munro *et. al*. 2011; Ruscillo, 2003; Davis, 1987) lo que nos permite diferenciar entre un género u otro.

El acetábulo es uno de los mejores indicadores para sexar en mamíferos debido a los efectos de la reproducción sobre el esqueleto (Greenfield, 2002). Por ello, el presente trabajo basándose en estudios previos (Greenfield, 2002; Von den Driesh, 1976) se centra en aquellos indicadores más útiles para sexar a través de acetábulo en bóvidos con el objetivo de proporcionar una base analítica para las interpretaciones en la adquisición de carcasas por parte de grupos humanos.

Si tenemos en cuenta el ACP (Figura 12), éste proporciona dos componentes de solución en los cuales el > 97% de la muestra de la varianza es explicado. El primer componente es explicado por la mayor parte de la inercia (85.25%), comparado con el segundo componente (11.95%). Las elipses de confianza muestran que no hay solapamiento en el 95% de los intervalos de confianza en las submuestras de machos y hembras. Cuando la muestra es analizada según el taxón, se observa que se solapan totalmente, lo cual documenta que la separación del sexo es proporcionada por las variables usadas no depende ni de la especie ni de la talla del animal.

H2_LA2 (0.9366) y H2_LA (0.9363) son las dos variables que mejor determinan el primer componente, con una correlación de >0.9, seguida de otras ratios. Las puntuaciones para el segundo componente se distribuyen de forma más uniforme entre todas las variables, mostrando H2 la puntuación más alta (0.4). El resto de variables se encuentran entre 0.34 y 0.37.

El ACP sugiere que la variable con la mayor puntuación para el primer componente debería ser elegida en la regresión logística (RL) (Figura 13). Ésta produce una solución en la cual H2_LA2 es nuevamente seleccionada como la variable más útil para identificar ambos sexos según el taxón. La regresión logística muestra que la probabilidad de identificar correctamente una hembra basado en la altura acetabular y la longitud supera el 80% cuando la ratio es >0.2 y los mismo es aplicado para identificar la mayor parte de los machos cuando la ratio H2_LAR2 es >0.3.

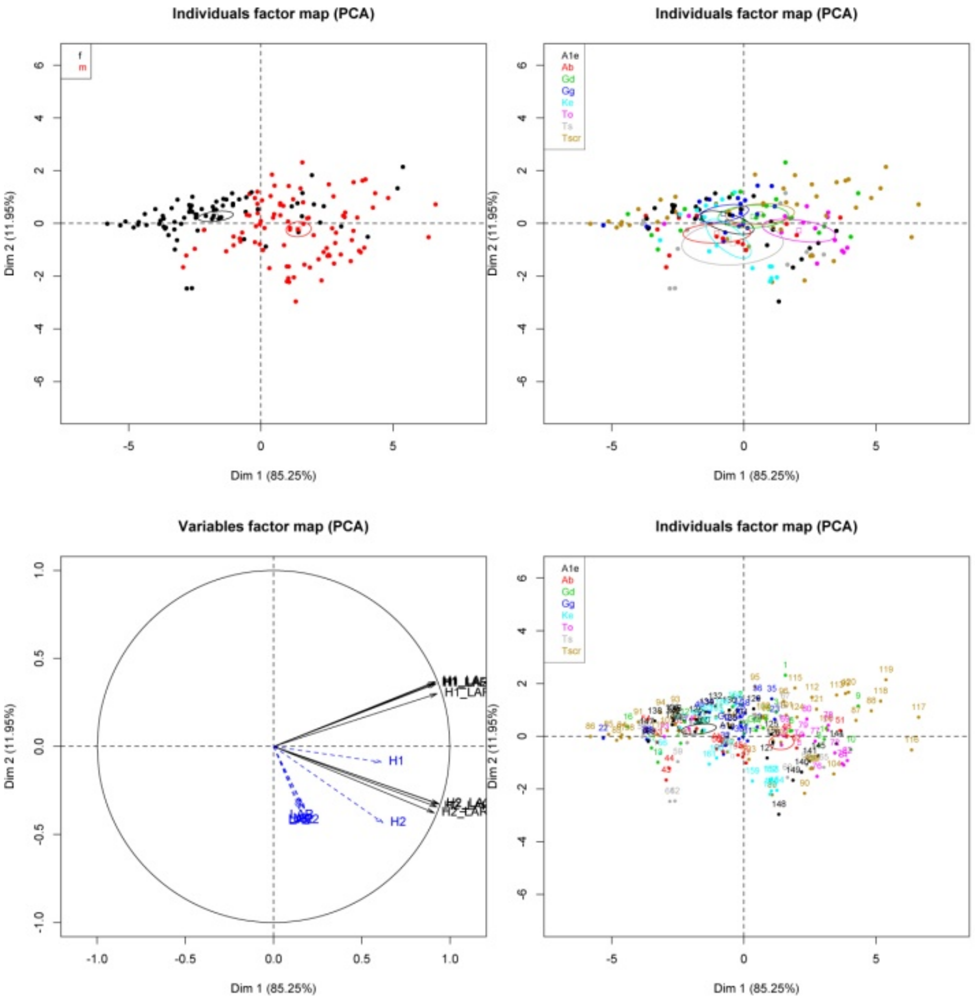


Figura 12. Análisis de componentes principales.

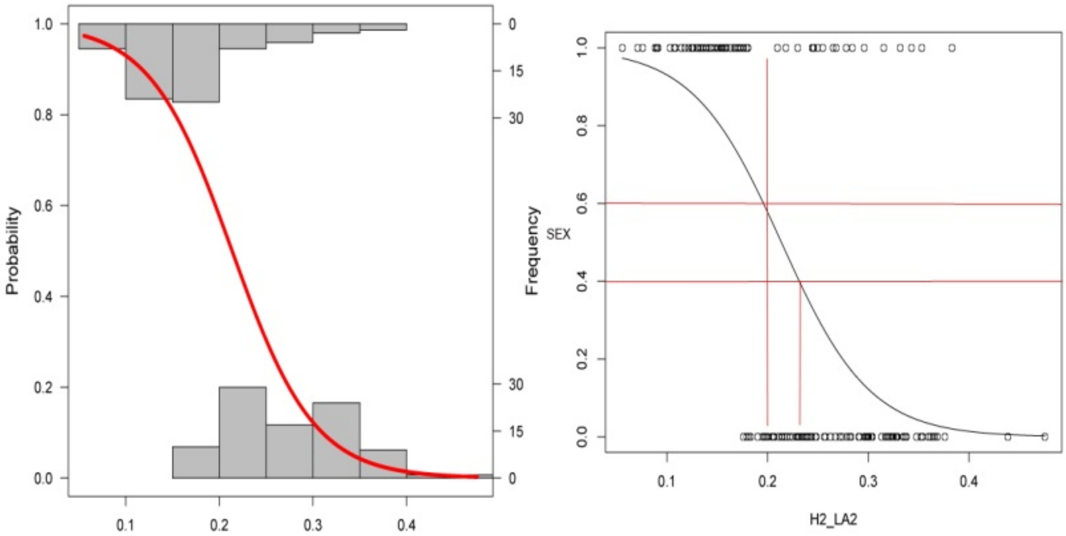


Figura 13. Regresión logística.

DISCUSIÓN

Distribución anatómica de las marcas de corte de descarnado y desarticulado.

Tanto Nilssen como Binford (Binford 1981,105) emplean navajas de metal en sus experimentos y observaciones etnográficas. Incluso Nilssen llega a emplear en algunos casos sierras para cortar, y de forma marginal útiles líticos (Nilssen 2000, 117). Por lo tanto, a pesar de control que puedan tener como es el caso de Nilssen, no pueden ser aplicados al registro arqueológico, debido a que su aproximación no es real, ya que la localización anatómica de las marcas de corte al emplear navajas de metal es diferente a cuando se emplean herramientas de piedra.

A pesar del especial énfasis que hace Nilssen (2000) en la importancia de la localización anatómica de las marcas de corte, su orientación y ángulo, estos factores son limitados. Según lo documentado en el presente estudio, depende de un conjunto de variables, incluyendo el tipo de herramienta empleado y la experiencia de la persona encargada de realizar la actividad de carnicería (Padilla, 2008).

Nilssen afirma que algunas marcas de descarnado y desarticulado se encuentran localizadas en superficies articulares (Nilssen 2000, 238), y de hecho aporta documentación experimental. Sin embargo, basándonos en la documentación de marcas de descarnado del presente trabajo, este tipo de marcas no aparecen en estas localizaciones. La aparición de marcas de corte en esas áreas se debe al uso de herramientas de metal, ya que debido a la delgadez de la hoja pueden ser fácilmente introducidas en las articulaciones, algo que no ocurre si empleamos un útil lítico debido a su grosor.

Las diferencias en la interpretación de Binford (1981) y de Nilssen (2000) en la distribución de las marcas de corte en los extremos de los huesos con el presente trabajo son expuestas a continuación en las tablas 4 y 5.

Código	*Hueso*	*Localización*	*Nilssen*	*Galán*
Hp-1	Húmero	Borde de la cabeza articular	Descarnado	Desarticulado
Hp-2	Húmero	Apéndice de la tuberosidad lateral	Descarnado	Nada
Hp-3	Húmero	Cara lateral del cuello sobre la tuberosidad.	Descarnado	Nada
Hp-4	Húmero	Tuberosidad de la inserción del teres menor.	Descarnado	Nada
Hp-5	Húmero	Lado medial: zona inferior de la cabeza.	Descarnado	Nada
Hp-6	Húmero	Superficie articular de la cabeza.	Desarticulado	Nada
Hp-7	Húmero	Lado medial: borde de la cabeza.	Descarnado	Nada
Hp-8	Húmero	Lado craneal: tuberosidad medial.	Desarticulado	Nada

Hp-9	Húmero	Lado craneal: tuberosidad medial.	Descarnado	Nada
Hp-10	Húmero	Lado craneal: tuberosidad lateral.	Desarticulado	Nada
Hp-11	Húmero	Lado caudal: tuberosidad lateral.	Descarnado	Nada
Hp-12	Húmero	Lado caudal: tuberosidad lateral.	Desarticulado	Nada
Hp-13	Húmero	Lado caudal: tuberosidad medial.	Desarticulado	Nada
Hd-1	Húmero	Tróclea.	Desarticulado	Desarticulado
Hd-2	Húmero	Zona superior de la tróclea y epicóndilo medial.	Descarnado y/o Desarticulado	Descarnado y/o Desarticulado
Hd-3	Húmero	Epicóndilo lateral y epífisis distal.	Descarnado y/o Desarticulado	Descarnado y/o Desarticulado
Hd-4	Húmero	Epicóndilo lateral y tróclea.	Desarticulado	Desarticulado
Hd-8	Húmero	Epicóndilo medial.	Descarnado	Desarticulado
Hd-9	Húmero	Tróclea.	Descarnado	Desarticulado
Hd-10	Húmero	Tróclea.	Descarnado	Desarticulado
Hd-11	Húmero	Epicóndilo lateral.	Descarnado	Desarticulado
Hd-12	Húmero	Epífisis distal en lado caudal.	Descarnado	Nada
Hd-13	Húmero	Epicóndilo medial.	Desarticulado	Desarticulado
Hd-14	Húmero	Tróclea.	Desarticulado	Desarticulado
RCp-2	Radio-ulna	Lado lateral de la ulna.	Descarnado	Desarticulado
RCp-3	Radio-ulna	Lado medial de la ulna.	Descarnado	Desarticulado
RCp-4	Radio-ulna	Lado medial en la muesca semilunar.	Desarticulado	Desarticulado
RCp-5	Radio-ulna	Lados medial, lateral y margen caudal de la tuberosidad radial y el proceso anacóneo.	Desarticulado	Desarticulado (no en todas las localizaciones)
RCp-6	Radio-ulna	Bajo las tuberosidades medial y lateral del radio.	Descarnado	Desarticulado
RCp-7	Radio-ulna	Lados medial y lateral de la caña de la ulna.	Descarnado	Descarnado y/o Desarticulado
RCp-8	Radio-ulna	Tuberosidad radial en lado caudal.	Descarnado	Desarticulado
RCp-9	Radio-ulna	Tuberosidad radial en lado medial.	Descarnado	Desarticulado
RCp-10	Radio-ulna	Borde caudal del olecranon.	Descarnado	Desarticulado
RCp-11	Radio-ulna	Superficie lateral de la tuberosidad radial.	Descarnado	Descarnado y/o Desarticulado
RCp-12	Radio-ulna	Lados lateral y medial del olecranon.	Descarnado	Desarticulado
RCp-13	Radio-ulna	Margen del lado lateral de la muesca semilunar.	Desarticulado	Nada

RCp-15	Radio-ulna	Tuberosidad radial (vista caudal).	Descarnado	Desarticulado
RCp-17	Radio-ulna	Borde medial de la tuberosidad radial.	Desarticulado	Desarticulado
RCd-2	Radio-ulna	Superficie articular del proceso estiloide.	Desarticulado	Nada
Fp-1	Fémur	Cuello del fémur.	Descarnado y/o Desarticulado.	Desarticulado
Fp-2	Fémur	Cabeza del femur.	Desarticulado	Nada
Fp-3	Fémur	Cabeza del femur.	Descarnado	Nada
Fp-4	Fémur	Trocánter menor.	Descarnado	Desarticulado
Fp-5	Fémur	Trocánter mayor.	Descarnado	Nada
Fp-6	Fémur	Sobre el cuello del fémur.	Descarnado	Descarnado y/o Desarticulado
Fp-7	Fémur	Cuello del trocánter mayor.	Descarnado	Nada
Fp-9	Fémur	Zona superior de la caña.	Descarnado	Nada
Fp-10	Fémur	Trocánter mayor en lados caudal y lateral.	Descarnado	Nada
Fp-11	Fémur	Trocánter mayor (lado craneal)	Descarnado	Nada
Fp-12	Fémur	Trocánter mayor (lado craneal)	Desarticulado	Nada
Fp-13	Fémur	Alrededor de la cabeza del fémur (lados craneal y caudal)	Desarticulado	Nada
Fp-14	Fémur	Trocánter mayor (vista caudal)	Descarnado	Nada
Fp-15	Fémur	Superficie de la cabeza del fémur.	Descarnado	Nada
Fd-1	Fémur	Epicóndilos medial y lateral y sobre el cóndilo medial.	Descarnado y/o Desarticulado	Desarticulado
Fd-2	Fémur	Tróclea (lados medial y caudal).	Descarnado	Nada
Fd-3	Fémur	Cóndilos lateral y medial (lado ventral de la articulación distal)	Desarticulado	Nada
Fd-4	Fémur	Parte distal de la diáfisis en vista caudal.	Descarnado	Descarnado
Fd-5	Fémur	Sobre tróclea.	Descarnado	Desarticulado
Fd-6	Fémur	Epicóndilos medial y lateral.	Descarnado	Desarticulado
Fd-7	Fémur	Epicóndilos medial y lateral; cóndilo lateral.	Desarticulado	Desarticulado
Fd-8	Fémur	Cóndilos lateral y medial (lado ventral de la articulación distal).	Desarticulado	Nada
Tp-1	Tibia	Alrededor de los tubérculos intercondilares.	Desarticulado	Nada
Tp-2	Tibia	Cóndilos lateral y medial (lados craneal y medial).	Desarticulado	Nada
Tp-3	Tibia	Cresta de la tibia en vista lateral.	Descarnado	Descarnado

Tp-4	Tibia	Bajo la superficie articular (vista medial).	Descarnado	Nada
Tp-5	Tibia	Parte superior de la diáfisis en vista medial.	Descarnado	Nada
Tp-6	Tibia	Borde de la superficie articular del cóndilo medial y la superficie superior de la tuberosidad en lado craneal.	Desarticulado	Nada
Tp-7	Tibia	Epífisis proximal (lados caudal y lateral).	Descarnado	Nada
Td-1	Tibia	Maleolo medial.	Desollado y/o Descarnado	Nada
Td-5	Tibia	Epífisis distal (lados craneal y medial).	Desollado	Nada
Td-6	Tibia	Zona distal de la diáfisis.	Desollado y/o Descarnado	Desarticulado

Tabla 4. Interpretación de Nilssen de los tipos de marcas de Binford de acuerdo a su trabajo experimental y comparación con el presente estudio.

Código	***Hueso***	***Localización***	***Binford***	***Galán***
Hp-1	Húmero	Labio de la cabeza.	Desmembramiento	Desarticulado
Hp-2	Húmero	Tubérculo mayor.	Desmembramiento	Nada
Hp-3	Húmero	Tuberosidad lateral.	Desmembramiento	Desarticulado
Hp-4	Húmero	Tuberosidad lateral.	Descarnado	Desarticulado
Hp-5	Húmero	Sobre cabeza.	Descarnado	Descarnado
Hd-1	Húmero	Tróclea.	Desmembramiento	Desarticulado
Hd-2	Húmero	Sobre tróclea.	Desmembramiento	Desarticulado
Hd-3	Húmero	Epífisis distal.	Desmembramiento	Desarticulado
Hd-4	Húmero	Epicóndilo lateral y lado ventral de la tróclea.	Desmembramiento	Desarticulado (excepto en lado ventral)
Hd-6	Húmero	Sobre tróclea.	Descarnado	Nada
Hd-7	Húmero	Sobre epicóndilo medial.	Descarnado	Nada
RCp-2	Radio-ulna	Lado lateral de la ulna.	Desmembramiento	Desarticulado
RCp-3	Radio-ulna	Lado medial de la ulna.	Desmembramiento	Desarticulado
RCp-4	Radio-ulna	Borde de la muesca semilunar (vista medial).	Desmembramiento	Nada
RCp-5	Radio-ulna	Tuberosidad radial (lados lateral, craneal y medial).	Desmembramiento	Desarticulado
RCp-6	Radio-ulna	Zona proximal de la díafisis.	Descarnado	Nada
RCp-7	Radio-ulna	Caña de la ulna.	Descarnado	Nada
RCd-1	Radio-ulna	Epífisis distal (radio).	Desmembramiento	Nada
RCd-2	Radio-ulna	Epífisis distal (ulna).	Desmembramiento	Nada
RCd-3	Radio-ulna	Epífisis distal (lados craneal y lateral).	Descarnado	Descarnado (sólo Bifaz)

Fp-1	Fémur	Cuello del fémur.	Desmembramiento	Desarticulado
Fp-2	Fémur	Cabeza del fémur.	Desmembramiento	Nada
Fp-3	Fémur	Cabeza del fémur.	Desmembramiento	Nada
Fp-4	Fémur	Trocánter menor.	Desmembramiento	Nada
Fp-5	Fémur	Trocánter mayor.	Desmembramiento	Nada
Fp-6	Fémur	Sobre el cuello del fémur (lado craneal).	Descarnado	Nada
Fp-7	Fémur	Sobre trocánter mayor (lado craneal).	Descarnado	Descarnado (sólo Bifaz)
Fp-8	Fémur	Sobre cabeza de fémur (lado caudal).	Descarnado	Nada
Fp-9	Fémur	Área proximal de la diáfisis.	Descarnado	Nada
Fd-1	Fémur	Cóndilos lateral y medial y sobre los mismos.	Duda	Duda
Fd-2	Fémur	Tróclea.	Desmembramiento	Nada
Fd-3	Fémur	Cóndilos lateral y medial (superficie articular, vista ventral).	Desmembramiento	Nada
Fd-4	Fémur	Sobre cóndilos medial y lateral.	Descarnado	Nada
Fd-5	Fémur	Sobre la tróclea.	Descarnado	Nada
Tp-1	Tibia	Alrededor de los tubérculos intercondilares.	Desmembramiento	Nada
Tp-2	Tibia	Cóndilos lateral y medial.	Desmembramiento	Nada
Tp-3	Tibia	Lado lateral de la cresta tibial.	Descarnado	Nada
Tp-4	Tibia	Lado medial de la cresta tibial.	Descarnado	Nada
Tp-5	Tibia	Lado medial de la cresta tibial.	Descarnado	Nada
Td-1	Tibia	Epífisis distal (vista lateral).	Desmembramiento	Nada
Td-2	Tibia	Superficie articular distal.	Desmembramiento	Nada
Td-3	Tibia	Maleolo medial.	Desmembramiento	Desarticulado
Td-4	Tibia	Área distal de la diáfisis.	Descarnado	Desarticulado

Tabla 5. Comparación de los tipos de marcas identificados por Binford en su estudio experimental con el presente trabajo.

Los patrones de marcas de corte producidos en el presente trabajo experimental han sido documentados en conjuntos arqueológicos. Así, las marcas de corte en huesos de ciervo procedentes de sitio Musteriense de Gabasa 1 (España) indican que la desarticulación tuvo lugar alrededor del área articular de la tibia, especialmente en su borde mesio-caudal, en la diáfisis en la cara craneal, en la zona supracondilar distal del fémur, en los trocánteres de la epífisis proximal del fémur, en el cuello del húmero (vista caudal) y en el epicóndilo distal (lateral y caudal) además de en la fosa radical sobre la tróclea del húmero (Blasco-Sancho, 1995).

Patrones similares también han sido documentados en lugares del Musteriense, Solutrense y Magdaleniense Ibéricos (Yravedra 2005). Sin embargo, la ausencia de documentación detallada sobre la localización anatómica de las marcas de corte en la mayor parte de lugares impide establecer comparaciones.

Sin embargo, cuando estos datos son reportados por los investigadores, varias de las características de las marcas de descarnado y desarticulado documentadas en el presente estudio son también observadas, e. g, Schöningen (Alemania), FLK Zinj (Garganta de Olduvai, Tanzania), BK (Garganta de Olduvai, Tanzania) (Voormolen, 2008; Bunn, 2001; Domínguez-Rodrigo *et al.*2009b).

Eficacia de lascas simples, lascas retocadas y bifaces

Estudios realizados en los años 90 mostraban como las lascas simples eran las herramientas más eficaces para tareas de carnicería en grandes animales (Schick y Toth, 1993). En sus experimentos, Schick y Toth (1993,166) apuntaban como las lascas simples necesitaban ser reemplazadas o que su filo fuese reavivado tras cinco o diez minutos de uso, mientras que las lascas retocadas proporcionaban una duración mayor. Sin embargo, tras los resultados del presente experimento, algunas lascas simples necesitaban ser reemplazadas después de una hora de uso o en el caso de las lascas retocadas, eran reemplazadas o su filo reavivado después de más de una hora. En el caso de los bifaces, a pesar de las diversas interpretaciones para su uso por parte de algunos investigadores (e.g., Schick y Toth, 1993; Gorman *et al*. 1995; Mitchell, 1996; Domínguez-Rodrigo *et al*. 2001), coincidimos en que su uso puede ser apto para actividades de procesado de carcasas.

El presente trabajo ha mostrado cómo los bifaces de menor tamaño pueden ser incluso más eficientes que las lascas para tareas de carnicería. Esto no quiere decir que todos los tipos de bifaces sean funcionales para este tipo de actividades. Los bifaces típicos de gran tamaño del ESA Achelense no son tan eficientes como los pequeños bifaces empleados en este experimento, debido a que su gran tamaño hace más difícil su utilización desde el punto de vista ergonómico. Además sus filos no son tan aptos para cortar carne.

Esto podría explicar de forma parcial porqué no hay una relación funcional clara entre los bifaces y la carnicería durante el Pleistoceno Inferior, ni porqué la mayoría de los yacimientos del Achelense más tempranos presenta una ausencia de fauna asociada o porqué cuando los análisis funcionales son llevados a cabo, los microresiduos hallados muestran diferentes tipos de actividades para las que fueron usados (e.g., Domínguez-Rodrigo *et al*. 2001). Sin embargo, durante la segunda mitad del Pleistoceno Medio, los análisis de huellas de uso sobre pequeños bifaces han proporcionado la inequívoca evidencia de pulir carne durante tareas de carnicería (Keeley, 1980; Mitchell, 1998; Ollé, 2005; Ollé *et al*. 2010).

Cuándo y por qué los homínidos empezaron a usar los bifaces para procesar carne es una cuestión controvertida. Olorgesailie es conocido por la abundancia de bifaces y los restos de fauna escasos (Isaac, 1977). Shipman *et al*. (1981) sugirieron que el procesado de babuinos se había producido en este yacimiento Achelense, aunque no existen indicaciones tafonómicas sólidas allí que apunten a ello. Si los bifaces son más eficientes, en términos de tiempo para procesar carcasas, su uso poco frecuente en el pasado para tareas de carnicería podría ser debido al coste introducido por la materia prima invertida y la conservación, como es sugerido en el presente estudio. En contra de este argumento se podría decir que los bifaces podrían ser continuamente reavivados para mayores períodos que las lascas, éstos podrían ser herramientas más eficientes desde el punto de vista de la inversión de material prima. Por ello, esta cuestión continúa siendo un tema a tratar para futuros trabajos experimentales. Si tales trabajos acaban por demostrar que la conservación de materia prima tienen un impacto menor en las decisiones de carnicería, la escasez de evidencia de homínidos empleando bifaces para procesar carcasas durante el Pleistoceno podría ser debido a que cualquiera de estas evidencias no dejan un rastro tafonómico o que el comportamiento de los homínidos no está siendo tan reduccionista como los enfoques de forrajeo óptimo pretenden que sea.

En consecuencia, el trabajo experimental aquí presentado muestra que los patrones de marcas de corte creados por tres conjuntos diferentes de herramientas de piedra no son diferentes cuando la persona que lleva a cabo el acto de carnicería es el mismo, en contra de la creencia de la naturaleza estocástica de estos patrones. Además, recientes estudios demuestran que el comportamientos de la fractura de los huesos culturalmente inducidos producen patrones en la distribución anatómica de las muescas de percusión y el descarnado también produce patrones anatómicos en la localización de las marcas de corte (Blasco *et al*. 2013). El presente trabajo experimental proporciona una evidencia más a favor de que las marcas de corte no son modificaciones estocásticas y que su localización anatómica está más estrechamente ligada al comportamiento de la persona que realiza la carnicería de lo que se preveía.

Análisis biométrico del acetábulo como indicador del sexo en bóvidos.

La mayor parte de los estudios de sexado se han centrado en contextos no paleolíticos (Davis *et al*. 2012; McGrory *et al*. 2012; Munro *et al*. 2011; Prummel y Frisch, 1986; Svensson *et al*. 2008; Tchernov *et al*. 1990; Zeder, 2001). Tan sólo algunos estudios han sido aplicados a conjuntos Paleolíticos. Weinstock (2000) reconstruye perfiles de sexo en el caso del reno para el yacimiento de Stellmoor (Alemania). Arceredillo *et al*. (2011) estudia el sexo en carcasas de *Rupicapra* con el objetivo de comprobar si los grupos Neandertales del yacimiento de Valdegoba (Burgos) tenían alguna preferencia en función del sexo a la hora de cazar rebeco, concluyendo que cazaban más sobre machos que hembras. D´Errico y Vanhaeren (2002) elaboraron un método para identificar el sexo de ciervos a través de caninos.

El presente estudio se ha basado en los trabajos de Greenfield (2002) y Von den Driesh (1976) con el objetivo de comprobar aquellas medidas más aptas para distinguir el sexo en bóvidos a través del acetábulo de la pelvis.

De acuerdo con Greenfield (2002) H1 es la medida que proporciona los resultados más claros y permite sexar de manera más efectiva. El presente trabajo apoya este hecho, siendo H1 una de las medidas más útiles para separar sexos. Sin embargo Greenfrield (2002) considera que H2 proporciona resultados menos satisfactorios que H1, es más difícil de tomar y por ello menos apta para identificar sexos.

Desde nuestro punto de vista y de acuerdo a los resultados aquí expuestos, H2 no sólo es ligeramente mejor que H1 para diferenciar sexos, a pesar de que la diferencia entre ambos sea pequeña, sino que H2 es una medida más fácil de tomar y que evita los errores de medida. Cuando H1 es tomada con el calibre existe la posibilidad de que los brazos de éste no se queden fijos en el centro de acetábulo. H2 proporciona por el contrario un punto estable de apoyo, dado que los brazos del calibre se ajustan a la pared del acetábulo, por lo que la posibilidad de movimiento es mínima.

Además, consideramos H2 como una “medida visual” debido a que es la única que permite identificar el sexo a primera vista, ya que en general, la pared del acetábulo es más baja en hembras que en machos (Greenfield, 2002). Otra ventaja ofrecida por esta medida es que puede ser aplicada en restos fragmentados, ya que sólo es necesaria la preservación de la pared medial (Greenfield, 2002), mientras que para el restos de indicadores es necesario el acetábulo completo.

Respecto a LA y LAR (Von den Driesch, 1976; Greenfield, 2002), si son aplicadas de forma aislada son menos efectivas que combinadas con H1 y H2 (en forma de ratio).

CONCLUSIONES

Las conclusiones de esta tesis son resumidas en los siguientes puntos a continuación:

- Creación de un nuevo mapa anatómico con la distribución de las marcas de descarnado desarticulado en los extremos de los huesos largos.
- Bifaces y lascas retocadas generan mayor número de marcas de corte en los huesos que las lascas simples.
- Los bifaces son más eficientes en términos de inversión de tiempo para el procesado de una carcasa. En el caso de la desarticulación de manera aislada, los tres conjuntos de útiles líticos presentan un tiempo muy similar.
- La distribución de marcas de corte no se produce al azar, son menos estocásticas de lo que se preveía, generando patrones similares y demostrables estadísticamente para los tres conjuntos de herramientas.
- Desde el punto de vista de la inversión de materia prima, las lascas simples son las más eficaces.
- El presente estudio crea una metodología estandarizada que puede ser aplicada en bóvidos sin tener en cuenta el taxón.
- La pared medial del acetábulo es el área más sensible de la pelvis para determinar el sexo, siendo H2 la medida más eficaz para distinguir machos y hembras en bóvidos africanos.

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AN EXPERIMENTAL STUDY OF THE ANATOMICAL DISTRIBUTION OF CUT MARKS CREATED BY FILLETING AND DISARTICULATION ON LONG BONE ENDS*

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Analogical frameworks created through experimentation are a vital part of taphonomic studies for interpreting the archaeological record. Understanding the anatomical location of cut marks is crucial for interpreting the butchery behaviour of humans in the past, as well as for indirectly inferring the subsistence and economic function of archaeological sites. Two experimental/ethnoarchaeological studies have provided taphonomists with analogues to interpret filleting and disarticulation butchery behaviours from archaeofaunal assemblages. However, these analogues were made with limited control and both involved the use of metal knives. The present work provides the first systematic and controlled study of cut mark distribution on long bones made with stone tools, aimed at differentiating cut marks created by filleting or defleshing from those inflicted during disarticulation. It also studies the variability of cut mark distribution according to stone tool type (simple flakes, retouched flakes and handaxes). The results show some differences with previous studies made with metal tools and offer an updated analogue to interpret butchery (filleting, dismembering and skinning) from prehistoric contexts.

KEYWORDS: CUT MARKS, SIMPLE FLAKES, RETOUCHED FLAKES, HANDAXES, DISARTICULATION, FILLETING, ANALOGY

INTRODUCTION

Descriptions of the characteristics of cut marks and of the criteria used to distinguish these marks from other types of marks have been made by several authors (e.g., Guilday *et al*. 1962; Walker and Long 1977; Bunn 1981; Potts and Shipman 1981; Shipman 1983; Cook 1986; Lyman 1987; Milo 1994; Fisher 1995; Greenfield 1999; Bello and Soligo 2008, Domínguez-Rodrigo *et al*. 2009a). Several of these works include descriptions of cut mark morphology, including macroscopic and microscopic characteristics. Walker and Long (1977) carried out experiments to define the types of cut marks produced by different stone tool cutting edges. Other studies have focused on the effectiveness of different stone tool types (Walker 1978). These determined that unretouched flakes are more effective than retouched flakes in butchery activities (Walker 1978). More recent studies have contributed to differentiating cut marks from trampling marks (Olsen and Shipman 1988; Domínguez-Rodrigo *et al*. 2009a), and have analysed cut mark morphology according to tool type: metal versus stone (Walker 1978; Greenfield 2006; Jones 2011), simple versus retouched flakes (Walker 1978; Domínguez-Rodrigo *et al*. 2009a) or handaxes (Bello *et al*. 2009; de Juana *et al*. 2010).

Systematic work on the behavioural meaning of the anatomical distribution of cut marks was first carried out by Binford (1981). His ethnoarchaeological work with the Nunamiut enabled

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anatomical mapping of cut marks according to butchering activities: skinning, dismembering and defleshing. Marks created by disarticulation clustered on long bone ends. Binford's work was followed by Nilssen's (2000) experimental butchery work. This produced some differences in the interpretation of the butchering process according to cut mark location. Whereas there was a broad agreement on the location of defleshing/filleting marks on shafts, some discrepancies emerged as to how filleting and disarticulation left marks on the metadiaphyseal and epiphyseal portions of long bones.

Differentiating defleshing from disarticulation is not a trivial question in zooarchaeological studies. Several distinctive behaviours of modern foragers can be zooarchaeologically reflected on the correct identification of disarticulation marks. For example, the Hadza hunter–gatherers (Tanzania) perform the disarticulation of limbs from the trunk as whole units to be transported at the loci of acquisition of carcasses (Bunn *et al.* 1988). Only distal limbs may be discarded disarticulated at near-kill locations (O'Connell *et al.* 1992). Once these carcass units reach home bases, they are extensively dismembered to be shared and prepared for cooking. Therefore, one of the criteria that could be used to argue whether a bone accumulation is found at or near the acquisition place or at the communal consumption place is the existence of one specific disarticulation pattern over another. However, attributing cut marks to defleshing or disarticulation is not a straightforward matter. Binford's observations did not stem from a protocol that included any control on the way in which cut marks were inflicted on bone surfaces. Binford studied assemblages *a posteriori*, after butchery had been performed, and attributed cut mark location *ad hoc*, according to whether cut marks occurred on certain parts of the ends or on shafts and based on prior observations of the butchery process. Nilssen's (2000) work constituted an improvement over Binford's foundational work. Nilssen recorded butchery, but he also attributed cut mark location *a posteriori*, supported by videographic documentation. However, attributing specific butchering actions as seen in film to specific cut marks identified on bones is also rather intuitive. There is no direct link between one action and its result.

Both Binford and Nilssen introduced a potential biasing factor into their studies. The butchery they recorded was performed with metal knives. There is a substantial difference in the outcome of a butchery process and its resulting cut mark pattern if using metal as opposed to stone tools, as reflected by the diversity of cut mark patterns that have been documented when using different stone raw materials (Dewbury and Russell 2006; Leenen 2011). Certain butchering actions, such as introducing the cutting tool in between the femoral distal condyles or using the tool as a wedge between articular surfaces, can be performed when using a metal knife but are not as easy when using a stone flake. This has potential repercussions *vis-à-vis* the resulting location of cut marks according to specific butchery behaviours. It could be argued that stone tools may produce different cut mark patterns from butchery performed with metal knives during disarticulation.

The present work targets this question by analysing cut mark patterns created exclusively during disarticulation of six carcasses, using three different stone tool sets. The study applied a direct control on the butchering process, by implementing a protocol that allowed unambiguously the distinction of cut marks created by defleshing from those inflicted during dismembering. The goal is to provide a more accurate anatomical map of cut marks on long bone ends depending on two of the main butchery behaviours: defleshing and disarticulation.

METHOD AND SAMPLE

A total of six deer (*Cervus elaphus*), whose weights were between 60 and 70 kg, were used in this study. They were acquired in legal organized hunting parties. Three experiments were conducted (two carcasses each) divided by type of stone tool: simple flakes, retouched flakes and handaxes. Although the goal of these experiments was to document the location of filleting and disarticulation marks on proximal and distal epiphyses, all the deer carcasses were completely filleted and disarticulated.

The six animals were butchered by an expert hunter (with 30 years of experience in butchery, using metal tools). Although this long experience with metal knives could have potentially resulted in a hindrance to the experiment, because the well-practiced pattern of butchery behaviour may not be efficiently replicated with stone tools, the butcher confessed to feeling at ease while using the stone tools and butchery was performed efficiently. Both filleting and disarticulation were made with the animal lying on one side on the floor. The butcher always used stone tools (except for evisceration) and followed this protocol: since most defleshing is produced by cutting the bulk flesh of long limbs perpendicular to the bone axis, filleting was carried out performing controlled perpendicular strokes to the bone axis, which resulted in the occurrence of perpendicular cut marks on bone surfaces. Disarticulation was carried out by employing oblique or parallel strokes to the bone axis (depending on the muscle or tendon insertion), creating an overwhelming majority of oblique cut marks. To improve the control, the whole process was videotaped as in Nilssen (2000). This was intended to help in case any mark was created with an ambiguous trajectory. When bones were cleaned, filleting and disarticulation cut marks could be clearly differentiated simply by the orientation of their trajectory.

Butchery was performed as follows (Fig. 1). First, the deer was gutted in the field with a metal knife in order to make the carcass lighter for transportation to a secondary butchery spot. This was done carefully, and the only potential marks created during this process may occur on the ventral side of ribs. Then the animal was skinned. This activity was carried out by cutting around the proximal epiphysis of metacarpals and metatarsals, and on the medial and lateral sides of tarsals and carpals. Then the skin was removed with stone tools and by pulling the skin off the carcass. When the deer was totally skinned, the next step was to fillet each bone, without disarticulating them. If disarticulation had been performed previous to defleshing, as in Nilssen's MRM study (Nilssen 2000, 103), the joint would have been manipulated in a way that would have rendered the control of the resulting cut mark types more difficult.

After filleting, disarticulation was carried out from hindlimb to front limb. Femora and humeri were dismembered from pelves and scapulae, respectively. When each deer was completely disarticulated, the bones were buried (always grouped according to individual animal) for 6 months to allow the soil to clean them naturally. They were then dug up and cleaned only with water to remove adhering sediment.

For the analysis of cut marks, we focused on those occurring on epiphyses and metadiaphyses, since most disarticulation leaves most marks on these sections, with some exceptions on distal radii and distal tibiae (see below). Marks were first identified by naked eye and then studied with the aid of hand lenses (15×). When all the cut marks had been located on each bone, they were drawn on templates of each bone type, using Adobe Photoshop CS4. In the drawings, disarticulation cut marks were drawn as oblique red strokes and filleting cut marks were drawn as perpendicular green strokes. Skinning cut marks on metacarpals and metatarsals were drawn in a blue colour. The degree of obliqueness used for the angle at which the disarticulation strokes were performed made the identification of the resulting cut marks on bones easy, because they contrasted sharply with the perpendicular marks created by filleting. Only in three instances were marks either too oblique or imperfectly perpendicular. These were discarded from the analysis, since they could not be securely attributed to specific butchery behaviours.

Figure 1 *Defleshing (upper) and disarticulation (lower) conducted during the experiments.*

Statistical analyses were carried out using the program R (http://www.r-project.org). To compare whether the three experimental butchery sets (made with simple and retouched flakes and handaxes) had a similar amount of cut marks, ANOVA tests were used. The function ‘oneway.test’ was used, since it can be applied to heterocedastic samples. Bonferroni tests were carried out in pairwise comparisons. Prior to analysis, the original samples, which were smaller than recommended for tests comparing sample dispersion and central tendency values, were bootstrapped 500 times.

RESULTS

A total of 205 cut marks were generated by defleshing and 1259 cut marks were made by disarticulating long bones, with only 107 cut marks created during skinning (Table 1). All these marks were counted on the epiphyseal and metadiaphyseal sections of all limb elements. This shows that cut marks made by disarticulation are predominant on long bone epiphyses and metadiaphysis by an order of >6:1.

ANOVA tests show that the three tool sets produce different numbers of cut marks ($F = 30.6439$; $p = 0.000$), mainly because of the higher number of marks created by handaxes (Table 1). Bonferroni tests show that the proportions of cut marks created by retouched flakes and handaxes are similar ($p = 0.74$), whereas marks made by simple flakes differ significantly from those made with the other tool sets ($p = 0.000$).

When dividing the cut mark sample according to the two butchery behaviours that created most of the marks, the greatest differences among the three tool sets is documented in defleshing ($F = 136.7169$; $p = 0.000$), with all pairwise comparisons being significantly different ($p = 0.000$). This contrasts with the resulting number of cut marks from disarticulation, in which the three types of tools yielded similar results ($F = 1.7979$; $p = 0.1662$).

Humerus

Experiments with simple flakes (Fig. 2 (a)) Disarticulation cut marks are concentrated on the distal epiphysis and metadiaphysis, especially on the medial and lateral sides. On the lateral side, marks cluster mainly along the epicondyloid crest. Marks on the distal epiphysis occur mainly on the trochlea and just above it. On the proximal epiphysis, marks were produced on the neck of the humerus, especially on the medial side, and some marks occur on the caudal and lateral sides. A few marks are located in the line between the intertubercular groove and the articular head.

Filleting cut marks are more numerous on the distal metadiaphysis, especially on the medial side, and in some cases they overlap with disarticulation marks. Certain marks occur on the caudal side on the upper section of the epicondyles. On the proximal epiphysis, filleting cut marks are located on the cranial and lateral sides of the neck.

Experiments with retouched flakes (Fig. 2 (b)) Disarticulation cut marks are concentrated on the distal epiphysis and metadiaphysis as above. They are particularly numerous on the caudal, medial and lateral sides. A few marks appear on the trochlea and above it, on both sides of the supratrochlear fossa. On the proximal epiphysis, they occur on the neck (lateral side) and below the articular head (medial side).

Table 1 *The number of cut marks according to stone tool type and butchering behaviour*

Stone tool	*Defleshing*	*Disarticulation*	*Skinning*
Simple flake	62	366	18
Retouched flake	108	433	9
Handaxe	35	460	80
Total	205	1259	107

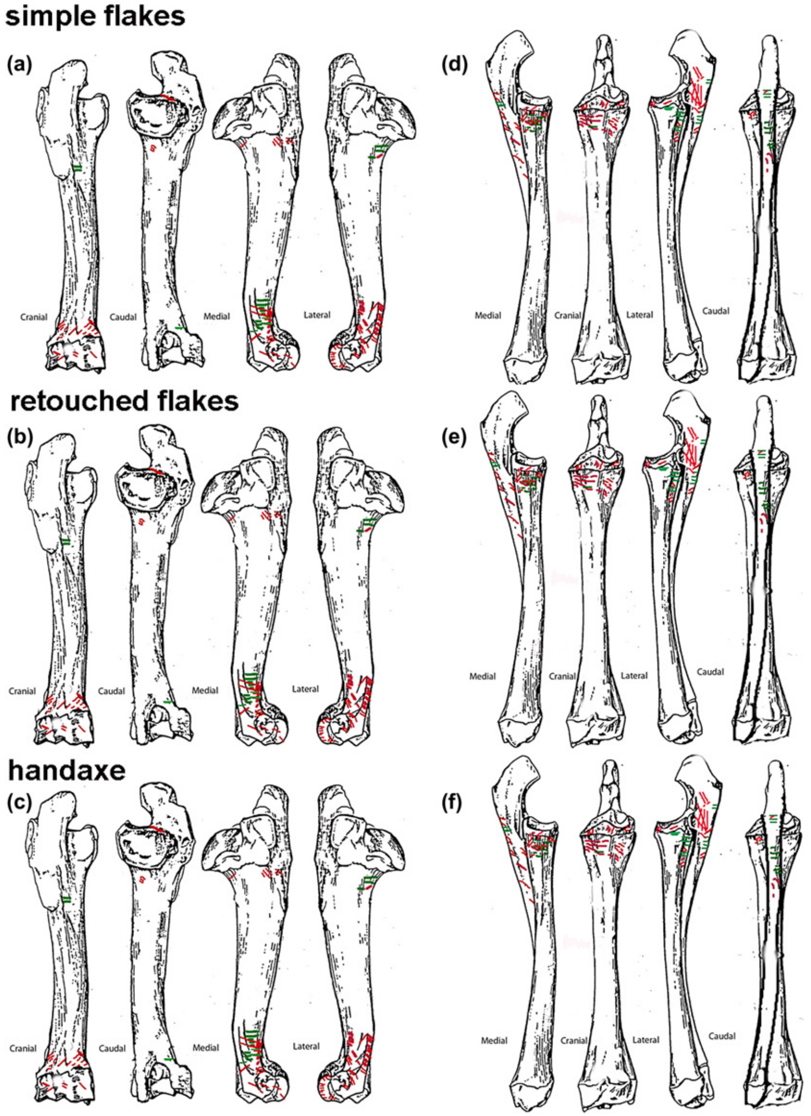

Figure 2 *The distribution of disarticulation cut marks (oblique/parallel lines) and filleting marks (perpendicular lines) on both ends of the humerus and the radius-ulna according to the tool type set: simple flakes (a,d), retouched flakes (b,e) and handaxes (c,f). (See online for a colour version of this figure.)*

Filleting cut marks on the distal epiphysis are concentrated above the trochlea and almost without overlap with disarticulation marks. They are also documented on the medial, caudal and lateral sides. On the proximal epiphysis, hardly any filleting marks were observed, mostly occurring on the lateral side of the neck.

Experiments with handaxes (Fig. 2 (c)) Disarticulation cut marks are located on the medial, lateral and cranial sides of the distal epiphysis. They occur less frequently on the caudal side. On the proximal epiphysis, a few marks are observed on the articular head and on the neck (lateral view).

Filleting cut marks are documented on the distal epiphysis and metadiaphysis, especially on the cranial and caudal sides and on the neck (lateral side) of the proximal epiphysis.

If we compare cut marks in the three experimental sets, we can observe how they are mainly distributed on the distal epiphysis (cranial, lateral and medial views), and less frequently on the proximal epiphysis. The main difference in the location of the disarticulation cut marks on the distal epiphysis occurs on the caudal side. These differences are frequent when using retouched flakes and were absent in the experiments using simple flakes or handaxes.

Radius-ulna

Experiments with simple flakes (Fig. 2 (d)) Disarticulation cut marks are exclusively concentrated on the proximal epiphysis of the radius, more specifically on the medial (radial tuberosity), cranial and lateral sides. On the ulna, cut marks appear clustered on the medial and lateral sides, and they occur less frequently on the caudal edge.

Filleting cut marks are also located on the proximal epiphysis and they overlap with disarticulation marks on the radial tuberosity (medial side). On the lateral side, filleting marks are more numerous than disarticulation marks and they occur without much overlap between the two types. On the ulna, defleshing cut marks are documented on the caudal edge, the lateral side and less frequently on the medial side. They have not been documented to overlap with disarticulation marks on this location.

Experiments with retouched flakes (Fig. 2 (e)) On the radius, disarticulation marks are only located on the medial, cranial and lateral views of the proximal epiphysis. On the ulna, they are observed on the medial and lateral sides and on the caudal edge.

Filleting cut marks occur on the medial and cranial sides of the proximal epiphysis. Cut marks on the cranial view overlap with disarticulation marks, but not on the medial side. On the ulna, filleting marks were found on the medial, lateral and caudal portions.

Experiments with handaxes (Fig. 2 (f)) Disarticulation cut marks are concentrated on the medial, lateral, caudal and cranial sides of the proximal radial epiphysis. On the distal epiphysis, disarticulation is represented by a few marks on the transverse crest. On the ulna, they are located on both the medial and the lateral sides.

Filleting cut marks on the radius occur both on the cranial side of the proximal and distal epiphyses. On the ulna, they are clustered on the lateral side and the caudal edge. They do not overlap with disarticulation cut marks.

If we compare cut marks according to the type of experiment, we can observe how cut marks made on the radius by both filleting and disarticulation occur in similar areas. All marks are concentrated on the proximal epiphysis on the cranial, medial and lateral views.

Regarding the ulna, both filleting and disarticulation cut marks occur on the medial, lateral and caudal sides, except for the handaxe sample, where disarticulation marks are not identified on the caudal side.

Metacarpal

All cut marks identified on both metacarpals and metatarsals were produced by disarticulation and skinning.

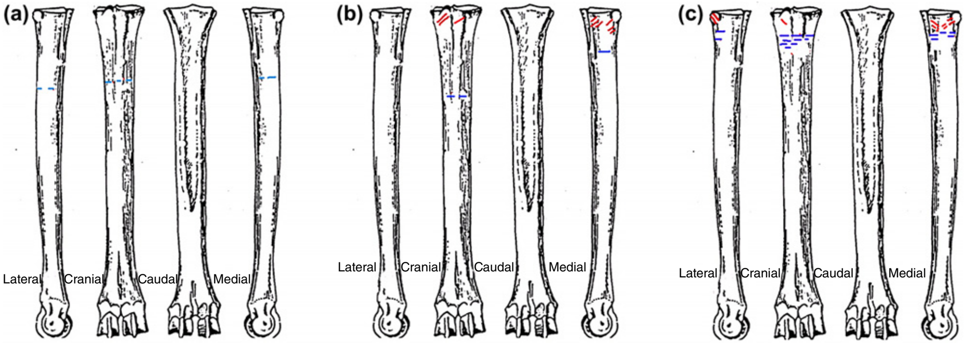

Figure 3 *The distribution of disarticulation cut marks (oblique/parallel lines) and skinning (perpendicular lines) on metacarpals according to the tool type set: simple flakes (a), retouched flakes (b) and handaxes (c). (See online for a colour version of this figure.)*

Experiments with simple flakes (Fig. 3 (a)) Cut marks clustered on the upper diaphysis are produced by skinning. They occur on the lateral, medial and cranial sides.

Experiments with retouched flakes (Fig. 3 (b)) The same as above.

Experiments with handaxes (Fig. 3 (c)) Cut marks on the proximal epiphysis (cranial, medial and lateral views) are produced by disarticulation.

No marks were identified on the caudal side.

Carpals

All cut marks were produced by disarticulation.

Femur

Experiments with simple flakes (Fig. 4 (a)) Disarticulation cut marks are distributed both on proximal and distal epiphyses. On the proximal epiphysis, they occur on the neck (medial side), the major trochanter, the proximal metadiaphysis (lateral side) and the intertrochanteric crest (near the lesser trochanter). On the distal epiphysis, disarticulation cut marks are located on the medial epicondyle, the lower part of the medial condyle, above the lateral condyle (below supracondyloid fossa and near it) and on the lateral condyle.

Filleting cut marks are only clustered on the major trochanter and on the trochanteric crest.

Experiments with retouched flakes (Fig. 4 (b)) On the proximal epiphysis, disarticulation cut marks are documented on the neck (medial and cranial sides) and below the major trochanter (cranial side). From the lateral view, cut marks are also concentrated below the major trochanter. On the distal epiphysis, disarticulation marks are located on the metadiaphysis (medial view), the medial epicondyle, above the lateral and medial condyles (caudal side) and on the articular facets of these condyles. On the lateral side, they are distributed on the epicondyle and the distal metadiaphysis.

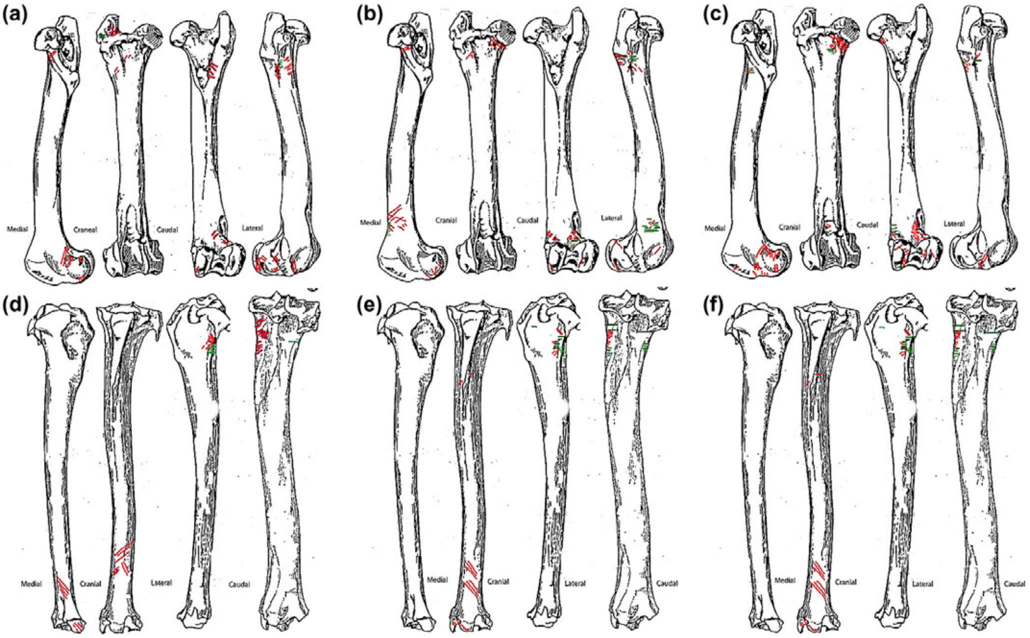

Figure 4 *The distribution of disarticulation cut marks (oblique/parallel lines) and filleting marks (perpendicular lines) on both ends of the femur and tibia according to the tool type set: simple flakes (a,d), retouched flakes (b,e) and handaxes (c,f). (See online for a colour version of this figure.)*

Filleting cut marks are found below the major trochanter, without overlapping with disarticulation cut marks. On the distal epiphysis they are documented above the lateral condyle (without overlapping with disarticulation cut marks) and on the distal metadiaphysis (lateral and medial sides).

Experiments with handaxes (Fig. 4 (c)) Disarticulation cut marks occur on the neck of the proximal epiphysis (cranial and caudal sides), below the major trochanter (lateral view) and the proximal metadiaphysis (medial side). At this latter location, they overlap with filleting cut marks. On the distal epiphysis, they are located on the lateral and medial epicondyles, on the medial and lateral condyles, and right above them. On the cranial side, they are documented on the trochlea.

Filleting cut marks are located on the proximal metadiaphysis (cranial, lateral and medial views). On the distal epiphysis, they occur above the trochlea cranially and over the medial condyle (caudal view).

If the three experiments are compared, two common disarticulation areas on the proximal epiphysis can be observed: on the neck and below the major trochanter. On the distal epiphysis, disarticulation cut marks are clustered on the lateral and medial condyles and epicondyles.

Tibia

Experiments with simple flakes (Fig. 4 (d)) On the proximal epiphysis, disarticulation cut marks are documented on the proximal metadiaphysis (lateral side), just below the fibula insertion, and on the caudal lateral side. On the distal epiphysis, they are located on the maleollus and on the medial side of the distal metadiaphysis. Cut marks on the lower diaphysis are produced by cutting the tendons of the tibial and extensor muscles.

Filleting cut marks are only documented on the proximal epiphysis, specifically on the metadiaphysis (caudal and lateral views). They overlap with disarticulation marks on the lateral side.

Experiments with retouched flakes (Fig. 4 (e)) Disarticulation cut marks are located on the cranial side of the proximal epiphysis, below the tibial crest and on the metadiaphysis (lateral and caudal views). On the distal end, they occur on the medial malleolus, and caudal side of the epiphysis. Again, we can observe cut marks on lower diaphysis, produced by cutting the tibial or extensor muscles.

Filleting cut marks are only located on the proximal metadiaphysis (caudal and lateral views). They do not overlap with disarticulation marks.

Experiments with handaxes (Fig. 4 (f)) Only a few disarticulation cut marks were identified on the proximal epiphysis. They occur below the fibula insertion. On the distal epiphysis, they occur on the end of the joint and on the medial malleolus. Cut marks on the lower diaphysis are produced by cutting the tibial or extensor muscles.

With regard to filleting cut marks, they occur only below the fibula insertion, without overlapping with disarticulation cut marks.

If we compare the three experiments, we can observe several common areas for disarticulation cut marks: the malleolus and the area above it, the proximal metadiaphysis (lateral and caudal sides) and the lower diaphysis.

Filleting cut marks are concentrated on the lateral side of the proximal metadiaphysis.

Metatarsal

Experiments with simple flakes (Fig. 5 (a)) Disarticulation cut marks are located on the lateral side of the proximal epiphysis. Cut marks produced by skinning are concentrated on the upper diaphysis (lateral, medial and caudal sides).

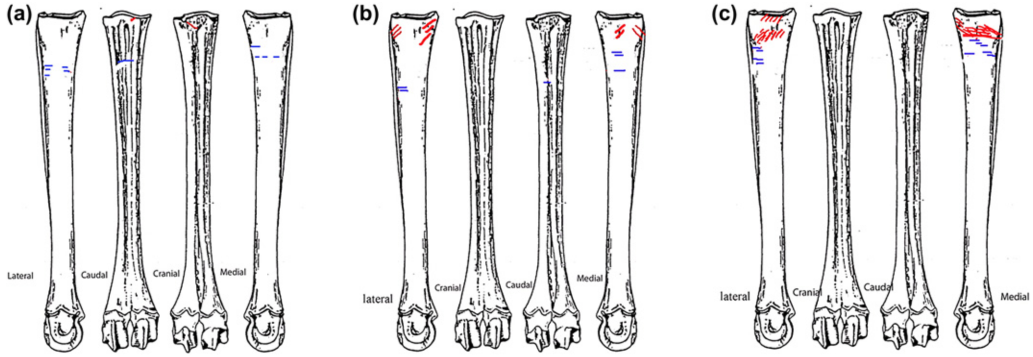

Figure 5 *The distribution of disarticulation cut marks (oblique/parallel lines) and skinning (perpendicular lines) on metatarsals according to the tool type set: simple flakes (a), retouched flakes (b) and handaxes (c). (See online for a colour version of this figure.)*

Experiments with retouched flakes (Fig. 5 (b)) Disarticulation marks are documented on the lateral and medial sides of the proximal epiphysis. We can again observe skinning cut marks on the upper diaphysis (caudal, lateral and medial views).

Experiments with handaxes (Fig. 5 (c)) The same as in the previous experimental set.

Tarsals

Like carpals, all cut marks observed were produced by disarticulation.

Cut mark distribution per experimental set

The results of the number of marks, by stone tool type and butchering activity, can be seen in Table 1. If we consider the number of cut marks by butchery activity, as reflected on epiphysial and metadiaphyseal sections, the number of disarticulation cut marks is substantially higher than the number of filleting marks.

If we divide the cut mark sample by the type of tool employed, handaxes produced a higher number of disarticulation and skinning marks than the other stone tools and the lowest number of filleting cut marks. Retouched flakes produced the highest number of filleting cut marks, and the smallest number of skinning marks. Simple flakes produced the lowest number of disarticulation cut marks.

If we consider the type of bone, disarticulation cut marks are more abundant on the humerus, followed by the radius, femur and tibia. Filleting cut marks are more numerous on the radius, followed by the humerus, femur and tibia.

DISCUSSION

Both Nilssen and Binford (Binford 1981, 105) used metal knives for butchery in their experiments and ethnographic observations. Nilssen also employed a saw in some cases and, only marginally, stone tools (Nilssen 2000, 117). These experiments, despite the limited control they had, are of limited value when applied to the prehistoric archaeological record, since the frequency and location of cut marks made with metal tools may be substantially different from those created by stone tools.

In spite of the emphasis that Nilssen places on the importance of the anatomical location, orientation and angle of cut marks (Nilssen 2000, 109), these are also of limited value, since they have been documented to depend on an array of variables, including the type of tool employed and the experience of the butcher (Padilla 2008). Nilssen (2000, 109) explains that it is more difficult to distinguish filleting from disarticulation marks as determined by the angle of cut marks made with stone tools compared to metal knives.

Nilssen shows that some filleting and defleshing cut marks are located on articular surfaces (Nilssen 2000, 238) and, in fact, he provides experimental documentation. In contrast, filleting marks obtained in the present experiment do not appear on these locations. This may also be in part due to the use of metal versus stone tools. When using the latter, due to their thickness, the tool cannot be introduced in between joints as easily as metal knives. This may be reflected in the lower frequency of marks created on these surfaces.

The differences in the interpretation of Binford's (1981) mark types on ends by Nilssen and our study are shown in Table 2. The differences in the functional interpretation of Binford's (1981) mark types and our study are shown in Table 3.

Table 2 *Nilssen's interpretation of Binford's cut mark types, according to his experimental work, and a comparison with the present study*

Code number	*Bone*	*Location*	*Nilssen*	*Present study*
Hp-1	Humerus	Edge of articular head	Filleting	Disarticulation
Hp-2	Humerus	Apex of the lateral tuberosity	Filleting	None
Hp-3	Humerus	Lateral face of the neck (above tuberosity)	Filleting	None
Hp-4	Humerus	Tuberosity of insertion of teres minor	Filleting	None
Hp-5	Humerus	Medial side: below head	Filleting	None
Hp-6	Humerus	Superior articular side of head	Disarticulation	None
Hp-7	Humerus	Medial side: edge of head	Filleting	None
Hp-8	Humerus	Cranial side: medial tuberosity	Disarticulation	None
Hp-9	Humerus	Cranial side: medial tuberosity	Filleting	None
Hp-10	Humerus	Cranial side: lateral tuberosity	Disarticulation	None
Hp-11	Humerus	Caudal side: lateral tuberosity	Filleting	None
Hp-12	Humerus	Caudal side: lateral tuberosity	Disarticulation	None
Hp-13	Humerus	Caudal side: medial Tuberosity	Disarticulation	None
Hd-1	Humerus	Trochlea	Disarticulation	Disarticulation
Hd-2	Humerus	Above trochlea and medial epicondyle	Filleting and/or disarticulation	Filleting and/or disarticulation
Hd-3	Humerus	Lateral epicondyle and distal epiphysis	Filleting and/or disarticulation	Filleting and/or disarticulation
Hd-4	Humerus	Lateral epicondyle and trochlea	Disarticulation	Disarticulation
Hd-8	Humerus	Medial epicondyle	Filleting	Disarticulation
Hd-9	Humerus	Trochlea	Filleting	Disarticulation
Hd-10	Humerus	Trochlea	Filleting	Disarticulation
Hd-11	Humerus	Lateral epicondyle	Filleting	Disarticulation
Hd-12	Humerus	Distal epiphisys on caudal side	Filleting	None
Hd-13	Humerus	Medial epicondyle	Disarticulation	Disarticulation
Hd-14	Humerus	Trochlea	Disarticulation	Disarticulation
RCp-2	Radio-ulna	Lateral side of ulna	Filleting	Disarticulation
RCp-3	Radio-ulna	Medial side of ulna	Filleting	Disarticulation
RCp-4	Radio-ulna	Medial side of semilunar notch	Disarticulation	Disarticulation
RCp-5	Radio-ulna	Medial, lateral and caudal margin of radial tuberosities and on anaconeal process	Disarticulation	Disarticulation (not in all locations)
RCp-6	Radio-ulna	Below lateral and medial tuberosities of radius	Filleting	Disarticulation
RCp-7	Radio-ulna	Medial and lateral side of ulna shaft	Filleting	Filleting and/or disarticulation
RCp-8	Radio-ulna	Radial tuberosity on caudal side	Filleting	Disarticulation
RCp-9	Radio-ulna	Radial tuberosity on medial side	Filleting	Disarticulation
RCp-10	Radio-ulna	Caudal border of olecranon	Filleting	Disarticulation
RCp-11	Radio-ulna	Lateral surface of radial tuberosity	Filleting	Filleting and/or disarticulation
RCp-12	Radio-ulna	Lateral and medial side of olecranon	Filleting	Disarticulation
RCp-13	Radio-ulna	Margin of lateral side of semilunar notch	Disarticulation	None
RCp-15	Radio-ulna	Radial tuberosity (caudal view)	Filleting	Disarticulation
RCp-17	Radio-ulna	Medial edge of radial tuberosity	Disarticulation	Disarticulation
RCd-2	Radio-ulna	Articular surface of styloid process	Disarticulation	None
Fp-1	Femur	Femur neck	Filleting and/or disarticulation	Disarticulation
Fp-2	Femur	Femur ball	Disarticulation	None
Fp-3	Femur	Femur ball	Filleting	None
Fp-4	Femur	Minor trochanter	Filleting	Disarticulation
Fp-5	Femur	Major trochanter	Filleting	None
Fp-6	Femur	Above femur neck	Filleting	Filleting and/or disarticulation
Fp-7	Femur	Neck of major trochanter	Filleting	None

Table 2 *(Continued)*

Code number	*Bone*	*Location*	*Nilssen*	*Present study*
Fp-9	Femur	Upper shaft	Filleting	None
Fp-10	Femur	Major trochanter (lateral and caudal sides)	Filleting	None
Fp-11	Femur	Major trocanter (cranial side)	Filleting	None
Fp-12	Femur	Major trocanter (cranial side)	Disarticulation	None
Fp-13	Femur	Around the femur ball (cranial and caudal sides)	Disarticulation	None
Fp-14	Femur	Major trocanter (caudal view)	Filleting	None
Fp-15	Femur	Ball surface	Filleting	None
Fd-1	Femur	Medial and lateral epicondyles and above medial condyle	Filleting and/or disarticulation	Disarticulation
Fd-2	Femur	Trochlea (caudal and medial sides)	Filleting	None
Fd-3	Femur	Lateral and medial condyles (ventral side of distal joint)	Disarticulation	None
Fd-4	Femur	Distal shaft of caudal view	Filleting	Filleting
Fd-5	Femur	Above trochlea	Filleting	Disarticulation
Fd-6	Femur	Medial and lateral epicondyles	Filleting	Disarticulation
Fd-7	Femur	Medial and lateral epicondyles; lateral condyle	Disarticulation	Disarticulation
Fd-8	Femur	Lateral and medial condyles (ventral side of distal joint)	Disarticulation	None
Tp-1	Tibia	Around intercondylar tubercles	Disarticulation	None
Tp-2	Tibia	Lateral and medial condyles (medial and cranial sides)	Disarticulation	None
Tp-3	Tibia	Lateral side of tibial crest	Filleting	Filleting
Tp-4	Tibia	Below articular surface (medial view)	Filleting	None
Tp-5	Tibia	Upper tibia shaft (medial side)	Filleting	None
Tp-6	Tibia	Edge articular surface of medial condyle and superior surface of tuberosity on cranial side	Disarticulation	None
Tp-7	Tibia	Proximal epiphisys (lateral and caudal sides)	Filleting	None
Td-1	Tibia	Medial malleolus	Skinning and/or filleting	None
Td-5	Tibia	Distal epiphisys (medial and cranial sides)	Skinning	None
Td-6	Tibia	Distal shaft	Skinning and/or filleting	Disarticulation

If we compare the results obtained in the present work to those reported by Nilssen (2000) and Binford (1981), we can observe the following:

1. Very few disarticulation cut marks on the humerus are coincident between Nilssen's study and the present work. In the case of Hd-13 and Hd-4, these occur on the edge of epicondyles, but they are more widely distributed in our sample.
2. Nilssen assigns most of the cut marks on the proximal ulna to filleting activity (e.g., RCp-10, RCp-3 and RCp-12; Nilssen 2000, 192); however, in our experiments, cut marks on this section caused by filleting are virtually absent and those documented are mostly produced by disarticulation. The only cut marks linked to filleting are those that appear on the caudal edge (lateral and medial sides). The present work agrees with Nilssen in the absence of filleting cut marks on the distal epiphysis of the radius, except in the experiment made with handaxes, which produced some cut marks on the cranial side. Nilssen observes disarticulation cut marks on the styloid process (RCd-2), and the proximal articular surface (Nilssen 2000, 194), but these were not reproduced in our experiments, probably because stone tools cannot be introduced between joints.

Table 3 *Binford's cut mark types, according to his experimental work, and a comparison with the present study*

Code number	*Bone*	*Location*	*Binford's Activity*	*Present study*
Hp-1	Humerus	Head lip	Disarticulation	Disarticulation
Hp-2	Humerus	Major tubercle	Disarticulation	None
Hp-3	Humerus	Lateral tuberosity	Disarticulation	Disarticulation
Hp-4	Humerus	Lateral tuberosity	Filleting	Disarticulation
Hp-5	Humerus	Above head	Filleting	Filleting
Hd-1	Humerus	Trochlea	Disarticulation	Disarticulation
Hd-2	Humerus	Above trochlea	Disarticulation	Disarticulation
Hd-3	Humerus	Distal epiphysis	Disarticulation	Disarticulation
Hd-4	Humerus	Lateral epicondyle and ventral side of trochlea	Disarticulation	Disarticulation (but not in ventral view)
Hd-6	Humerus	Above trochlea	Filleting	None
Hd-7	Humerus	Above medial epicondyle	Filleting	None
RCp-2	Radio-ulna	Lateral side of ulna	Disarticulation	Disarticulation
RCp-3	Radio-ulna	Medial side of ulna	Disarticulation	Disarticulation
RCp-4	Radio-ulna	Edge of semilunar notch (medial view)	Disarticulation	None
RCp-5	Radio-ulna	Radial tuberosity (lateral, cranial and medial sides)	Disarticulation	Disarticulation
RCp-6	Radio-ulna	Proximal shaft	Filleting	None
RCp-7	Radio-ulna	Ulna shaft	Filleting	None
RCd-1	Radio-ulna	Distal epiphysis (radio)	Disarticulation	None
RCd-2	Radio-ulna	Distal epiphysis (ulna)	Disarticulation	None
RCd-3	Radio-ulna	Distal epiphysis (cranial and lateral sides)	Filleting	Filleting (only Bifaz)
Fp-1	Femur	Femur neck	Disarticulation	Disarticulation
Fp-2	Femur	Femur ball	Disarticulation	None
Fp-3	Femur	Femur ball	Disarticulation	None
Fp-4	Femur	Minor trochanter	Disarticulation	None
Fp-5	Femur	Major trochanter	Disarticulation	None
Fp-6	Femur	Above femur neck (cranial side)	Filleting	None
Fp-7	Femur	Above major trochanter (cranial side)	Filleting	Filleting (only Bifaz)
Fp-8	Femur	Above femur ball (caudal side)	Filleting	None
Fp-9	Femur	Proximal shaft	Filleting	None
Fd-1	Femur	Lateral and medial condyles and above them	Duda	Duda
Fd-2	Femur	Trochlea	Disarticulation	None
Fd-3	Femur	Lateral and medial condyles (articular surface, ventral view)	Disarticulation	None
Fd-4	Femur	Above lateral and medial condyles	Filleting	Disarticulation
Fd-5	Femur	Above trochlea	Filleting	None
Tp-1	Tibia	Around intercondylar tubercles	Disarticulation	None
Tp-2	Tibia	Medial and lateral condyles	Disarticulation	None
Tp-3	Tibia	Lateral side of tibial crest	Filleting	None
Tp-4	Tibia	Medial side of tibial crest.	Filleting	None
Tp-5	Tibia	Medial side of tibial crest	Filleting	None
Td-1	Tibia	Distal epiphysis (lateral side)	Disarticulation	None
Td-2	Tibia	Distal articular surface	Disarticulation	None
Td-3	Tibia	Medial malleolus	Disarticulation	Disarticulation
Td-4	Tibia	Distal shaft	Filleting	Disarticulation

3. On the femur, cut marks labelled Fd-1 on condyles and linked to filleting (Nilssen 2000, 200) are also produced by disarticulation. Here, we have reproduced some filleting marks on the medial epiphysis only. On the ventral side of the distal joint, Nilssen finds filleting cut marks (Fd-2 and Fd-6; Nilssen 2000). This was not documented in our experimental work. The same occurs with some disarticulation cut marks that Nilssen observes on the femur head (Fp-2; Nilssen 2000, 202). The only coincidences between Nilssen's work and the present work on filleting cut mark location occur on metadiaphyses (medial and lateral sides). Cut marks labelled as Fp-7 are interpreted by Nilssen (2000, 202, fig. 4.269) as made by disarticulation, but in Nilssen (2000, 162, table 4.37), the same marks are attributed to filleting. These marks were produced by disarticulation in our work. Nilssen does not observe disarticulation on the distal metadiaphysis, on either the medial or caudal side, nor on the lateral side of the proximal metadiaphysis, below the major trochanter (Nilssen 2000, 202). In our experimental work, they occur in those areas.
4. On the tibia, several of the filleting cut marks that Nilssen reported (Nilssen 2000, 204–5) do not appear in our experiments. With regard to disarticulation cut marks, none of the marks attributed by Nilssen (Tp-1, Tp-2 and Tp-6) to this butchering behaviour (Nilssen 2000, 205) find correspondence in our experiments. They are located below the articular surface, not on it, probably due to the use of stone tools instead of metal knives. Cut marks labelled Td-6 are produced by filleting and/or disarticulation (Nilssen 2000, 204); however, in our experiments they are mostly produced by cutting the anterior tibial tendon. Td-1 cut marks produced by filleting according to Nilssen (2000, 204) do not occur in our experiments. Nilssen does not observe disarticulation cut marks on the distal epiphysis (Nilssen 2000, 205), but we document them on the distal end (cranial and medial sides).

If we compare the results of the present work with Binford's study, we can note the following:

1. On the humerus, dismembering cut marks labelled Hp-3 (Binford 1981, 123) occurring on the tuberosity have their correspondence with some disarticulation cut marks in one of our experiments carried out with retouched flakes. These types of marks are frequently observed on the medial neck. Disarticulation mark type Hd-2 (Binford 1981, 123) was also reproduced in our work, although above the trochlea, filleting cut marks also occur. The Hd-4 types (Binford 1981, 123) were also reproduced in our work and they are more numerous than those documented by Binford. The same can be applied to Hd-2 on the medial epicondyle. Filleting cut marks (Hp-5) on the neck of the humerus (Binford 1981, 133) are only verified with a few filleting marks documented in the experiment with retouched flakes.
2. On the ulna, Binford does not observe any cut marks (filleting or disarticulation) on the caudal side (Binford 1981, 125, 133). However, in our three experiments they appear on this location.
3. On the femur, Binford observes filleting cut marks such as Fp-8 between the intertrochanteric crest and the caudal side of the neck (Binford 1981, 131). These are, in contrast, very uncommon in our work.
4. On the tibia, we documented disarticulation cut marks on the proximal epiphysis in our work, whereas Binford does not. Only disarticulation cut marks labelled Td-3 (Binford 1981, 118) have been reproduced in our work.
5. Finally, Binford observes filleting cut marks on metapodials (e.g., MTd-4) (Binford 1981, 132). We have not reproduced these marks with the same butchering behaviour.

The cut mark patterns produced as a result of conducting filleting and disarticulation on long bone ends reported in the present experimental work have also been documented on archaeofaunal assemblages. Cut marks on deer bones from the Mousterian site of Gabasa 1 (Spain) indicating disarticulation have been found on the peri-articular area of the tibia, especially on its proximal mesio-caudal edge, and on its cranial distal shaft, on the supracondylar area of the distal femur, on the trochanters of the proximal femoral end, on the proximal caudal side of the humeral neck and the distal caudal lateral epicondyle, as well as the radial fossa above the humeral trochlea. This has been reported for several archaeological levels at the site (Blasco-Sancho 1995). Similar cut mark patterns have been documented at other Iberian Mousterian, Solutrean and Magdalenian sites (Yravedra 2005, pers. comm.). The lack of detailed anatomical documentation of cut mark locations at most sites makes comparisons rather difficult. However, when these are reported by researchers, several of the characteristics of filleting and disarticulation marks documented in the present work are also observed on even older archaeofaunal assemblages than mentioned above. For example, cut mark patterns documented at the middle Pleistocene site of Schöningen show several similarities with the patterns reported here (Voormolen 2008). For instance, cut marks on the caudal neck below the caput humeri, on the radial fossa, on the lateral face of the epicondyloid crest and on the lateral–cranial side of the capitulum of the humerus are similar to those documented in the present experiment. Cut marks reported on the proximal cranial shaft of the radius, on the femoral neck and trochanters, on the lateral supracondyloid fossa, on the medial distal condyle and supracondilar tuberosity of femora and on the proximal and distal ends of tibiae are also similar to the patterns of anatomical location reported in the present work. This comparison can also be extended to some of the few early Pleistocene sites where detailed descriptions and graphic representations of cut mark locations are reported. For instance, cut mark location on humeri and femora from FLK Zinj (Olduvai Gorge, Tanzania) as reported by Bunn (2001) and on humeri, femora, radius-ulnae and tibiae from BK (Olduvai Gorge, Tanzania) as reported by Domínguez-Rodrigo *et al*. (2009b) show similarities with the patterns experimentally replicated here using stone tools. This should encourage other researchers to report cut mark location and anatomical distribution with a similar degree of detail. This would improve the understanding of butchering behaviour in the past.

CONCLUSIONS

Most of our current analogical behaviour to understand cut mark distribution according to butchering behaviour stems from Binford's (1981) and Nilssen's (2000) ethnoarchaeological and experimental work, which was created through the use of metal knives. Although this was an approximate proxy for stone tool butchery, it did not reproduce the nuances of butchery when using stone tools, which are less versatile than metal knives in cutting through inter-joint areas and, therefore, leave a different imprint on bone surfaces, as the present study shows. This is the first experimental work using stone tools aimed at distinguishing cut marks on long bone ends created by filleting and disarticulation.

A summary of the results from this experiment shows that retouched flakes and handaxes leave more cut marks on bones than simple flakes. Despite this quantitative difference, butchery marks created by dismembering and filleting are similar overall in experiments using the three tool sets. On the head of the humerus, disarticulation cut marks are found in the experiments made with handaxes and simple flakes. Disarticulation cut marks on the trochlea also occur in the three experiments. Above the trochlea, both disarticulation and filleting cut marks can be observed. Disarticulation cut marks appear on the neck of humerus in the three experiments. On the medial and lateral epicondyles, a high number of disarticulation cut marks are reported. However, above them, on the distal and lateral metadiaphysis, cut marks are produced both by disarticulation and filleting.

On the radius-ulna, both disarticulation and filleting cut marks cluster on the proximal epiphysis (in contrast, on the humerus, most of the marks are concentrated at the distal epiphysis). Disarticulation cut marks appear mainly on the medial and lateral sides of the ulna and on the proximal epiphysis of the radius (medial, lateral and cranial sides). Filleting cut marks, in a smaller number, occur on the caudal edge of the ulna, and on the cranial, lateral and medial sides of the radial proximal epiphysis.

On the metapodials, cut marks are only documented on the proximal metadiaphysis, as a result of skinning, and on the proximal epiphysis, made by disarticulation.

On the femur, disarticulation cut marks are documented on the proximal epiphysis, clustering on the neck and on the intertrochanteric crest. At the distal epiphysis, they cluster on the lateral and medial condyles and epicondyles. These marks occur above the condyles and around the supracondylar fossa. A few filleting cut marks are also documented in the same area.

On the tibia, disarticulation cut marks occur on the proximal epiphysis and on the proximal metadiaphysis (caudal side). At the distal metadiaphysis, some marks traditionally attributed to defleshing are produced by cutting the anterior tibial tendon during disarticulation.

The present study is a preliminary step towards understanding the behavioural meaning of cut mark location on long bones. It has stressed important differences with previous experimental work that was carried out with metal knives and without as much control as the present work. This underscores the need to use homogeneous premises in experimental design between what is experimentally reproduced and the context to which analogies are applied (Domínguez-Rodrigo and Yravedra 2008). This study can be used to identify defleshing and disarticulation cut marks on prehistoric long bones and better support socio-economic interpretations of Pleistocene humans. Future work should help to refine the analogical framework presented here.

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TESTING THE EFFICIENCY OF SIMPLE FLAKES, RETOUCHED FLAKES AND SMALL HANDAXES DURING BUTCHERY*

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Handaxes, simple flakes and retouched flakes are three types of stone tools whose adaptive advantages are highly debated. Interpretations of these technologically different tools suggest that their adequacy for butchery is uneven. Although some experimentation has been made in this regard, further research is needed to understand which of these tool types are more efficient for butchery, thus granting adaptive advantages to the hominins who used them. The present experimental work shows that small handaxes provide higher return rates in butchery activities than simple and retouched flakes. Efficiency (measured in time) is significantly positive in handaxes compared to the other tools when defleshing. In contrast, when comparing the three stone tool sets (simple flakes, retouched flakes and handaxes), the return values obtained for disarticulation are very similar. This study also shows that cut marks do not occur randomly and are less stochastic than previously assumed. Defleshing leaves a preferential cluster of cut marks on mid-shafts from long bones and even on these sections, depending on element type, patterns are statistically demonstrable.

KEYWORDS: CUT MARKS, HANDAXES, ACHEULIAN, OLDOWAN, FLAKES, RETOUCHED FLAKES

INTRODUCTION

The balance between energy and/or time investment during carcass processing and the caloric yield obtained in the process is known as the return rate. Experimental return rates measure the net benefit of nutrient extraction through the interplay of processing time and nutritional gain: the latter is expressed in various ways (from the weight of each type of edible resource to their net caloric yield, according to the element type). This approach to the study of efficiency (understood as a process that minimizes processing time per caloric unit) and energy gain (understood as the process that maximizes caloric yields) is founded on optimal foraging principles. Return rate studies have been applied to the Pleistocene (e.g., Lupo 1998; Madrigal and Holt 2002; Marean and Cleghorn 2003). However, the elaboration of return rate analyses has sometimes yielded contradictory interpretations for butchery processes (e.g., Lupo 1998; Madrigal and Blumenschine 2000). Likewise, no correlation has been found between return rate and bone transport at modern ethnographic sites (Marean and Cleghorn 2003), probably because return rates have been derived without contemplating taphonomic biases (Egeland and Byerly 2005). Composite return rates (calculated by considering defleshing costs associated with demarrowing costs) suggest that available experimentally derived return rate data are more adequate for addressing carcass processing decisions, instead of carcass transport to sites (Egeland and Byerly 2005).

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Inspired within the framework of return rate studies, the efficiency of butchery (excluding demarrowing and degreasing) carried out with three different tool sets (simple flakes, retouched flakes and handaxes) is examined here. Assuming equal energetic yields through the butchery of the same types of carcasses, the question addressed was which of these types of tools allows a faster butchery process. Simple flakes have been traditionally presented as the most efficient way to butcher a carcass (e.g., Schick and Toth 1993). Use-wear analyses of Mousterian retouched flake tools have provided extensive evidence of their use in heavy-duty scraping activities such as hide working or woodworking, as well as meat removal (e.g., Keeley 1980; Beyries 1987, 1988). There is evidence in the form of phytoliths of the use of Lower Pleistocene handaxes for woodworking activities (Domínguez-Rodrigo *et al.* 2001); however, there is also microscopic evidence that late Middle Pleistocene handaxes were used for butchery (Keeley 1980; Mitchell 1997, 1998; Ollé 2005; Ollé *et al.* 2010). This is probably related to handaxe size, with the latter handaxes being substantially smaller than the former. This evidence can occur in the form of typical use-wear patterns (i.e., meat polish) on stone tool edges and, indirectly, through certain types of cut marks on bones (e.g., Yravedra *et al.* 2010), that are typical of handaxes, as documented during experimental butchery (de Juana *et al.* 2010). Sometimes both types of evidence occur together at the same site (Yravedra *et al.* 2010).

There is also experimental evidence that these types of tools can successfully compete against each other in butchery (Jones 1980, 1994). In an early descriptive experimental work, handaxes were suggested to be more efficient during butchery than simple and retouched flakes (Jones 1980). However, such an assertion was based on the personal experience of the butcher, who found handaxes less tiring than flakes, which were equally efficient, but no measurements were taken regarding the amount of time that each tool required (Jones 1980). Mitchell (1996) also experimentally documented that handaxes were useful butchery tools. However, the advantages and disadvantages of any of these types of tools during butchery remained insufficiently documented. Quantitative assessment of the efficiency of handaxes for butchery was carried out subsequently, and it was concluded that although some small relationship existed between symmetry and efficiency, it was the handaxe edge that was more important during butchery (Machin *et al.* 2005, 2007).

Following Machin *et al.*'s (2007) study on the efficiency of handaxes for butchery, in the present work, we will intend to provide data to address the following complementary and comparative questions:

1. Which of the three types of tools is more efficient in the butchering (skinning, defleshing and disarticulating) of large mammal carcasses?
2. Do the three types of tools generate the same cut mark patterns?
3. Which of the three types of tools is more efficient in the butchering of a carcass in terms of use of raw material?
4. Are edge length or tool mass correlated with butchery efficiency?

In addition, we used this experiment to address the question of whether cut mark patterns are random butchery accidents or if they follow a pattern of frequency and anatomical distribution that is determined by the ergonomy of stone tools in combination with the way in which muscle masses are attached to bones.

This study was designed with the interpretation that simple flakes are the most efficient butchery tools as a null hypothesis. The results will provide evidence that such a hypothesis is wrong if efficiency is measured in terms of butchering time alone, instead of also including raw material economics.

METHOD AND SAMPLE

In this work, a total number of six deer (*Cervus elaphus*), acquired in legally organized hunting parties, were used for experimentation. They were skinned, butchered and disarticulated with three different sets of stone tools (simple flakes, retouched flakes and handaxes), all of them made of flint, with the aim of testing the efficiency of each one during butchery. Each set of stone tools was used to butcher two deer. Every butchering activity was timed on each bone. Nine simple flakes, seven retouched flakes and three handaxes were used for this experiment. The mean length of the simple flake set was 57.45 mm (95% c.i. = 46.3–68.5). The average length of the retouched flake set was 54.28 mm (95% c.i. = 42.7–65.7). The mean length of the three handaxes used was 127 mm, but this is inaccurate since one handaxe was large (188 mm) and thick, and its edge was not suitable for the butchery, so it was discarded after a few seconds of use, and the remainder of the butchery was performed with two similarly sized small handaxes measuring 88 mm and 106 mm, respectively (Fig. 1). The stone tools were knapped by an experienced knapper. The handaxes are technologically and functionally good replicas.

The complete butchery process was performed by the same expert hunter (more than 30 years of experience). The butcher used a metal knife for the evisceration. He was assisted by another

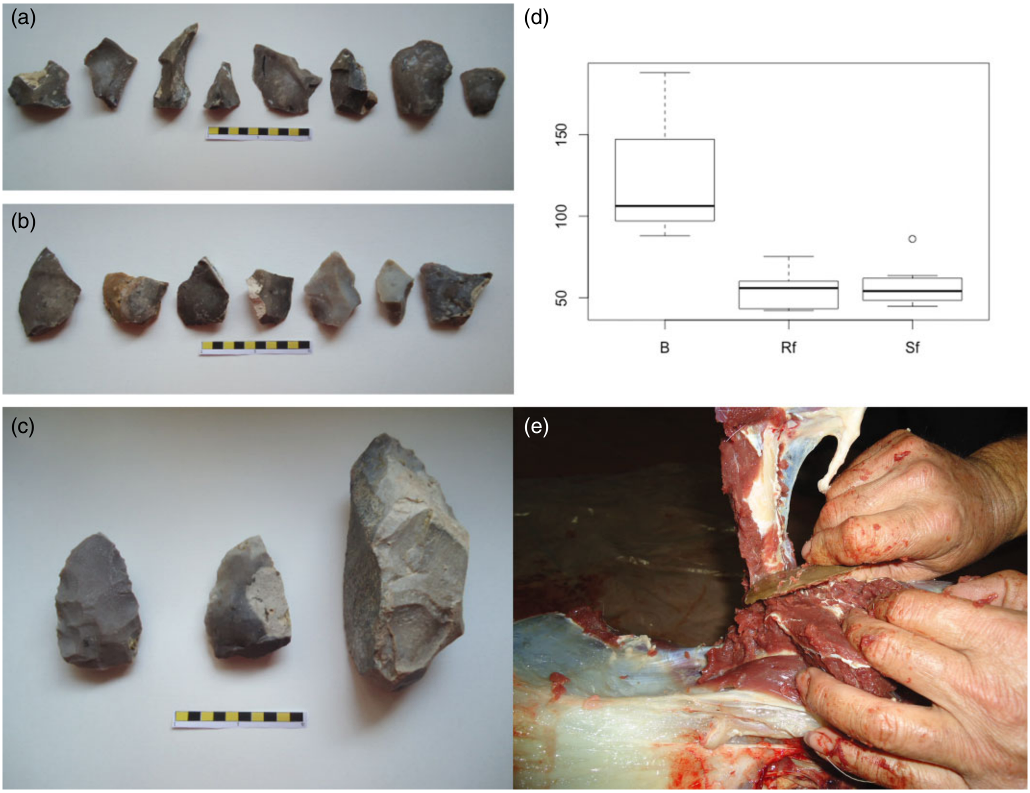

Figure 1 *The stone tools used for this experiment: (a) simple flakes; (b) retouched flakes; (c) handaxes; (d) a boxplot showing the lengths of the tools used (mm) (Sf, simple flakes; Rf, retouched flakes; B, bifacial handaxes); (e) an example of the use of a stone tool during butchery.*

person during skinning and disarticulation to hold the legs of the animal. Butchery was carried out with the animal on the floor (Fig. 1). The first step was to skin the deer using a stone tool (simple flake, retouched flake or handaxe). The first cuts were made around the proximal epiphysis of the metacarpus and metatarsus. When the deer was completely skinned, defleshing proceeded. Each bone was defleshed and the duration of this activity performed on every element was independently timed. Then, the same process was repeated during disarticulation. Every butchering activity was timed with a digital chronometer.

Butchery was carried out under strict control, by taking notes, photographing it and filming it on video. When butchery was finished, the bones were buried (separated by animal) for 6 months in a silty loam soil to clean them in a natural way. Finally, they were dug up and cleaned only with water and neutral soap to remove adhering sediment.

In order to evaluate if the resulting cut mark distribution was patterned, each long bone was divided into five sections—proximal epiphysis, proximal metadiaphysis, mid-shaft, distal metadiaphysis and distal epiphysis—and marks were tallied by section and side (cranial, caudal, medial and lateral) as described in Yravedra and Domínguez-Rodrigo (2009). They were also drawn on templates of each bone type using Adobe Photoshop CS5.

Statistical methods

Analyses of variance were used in the present study. Bartlett's tests provided information about the equality/inequality of variances of the samples used. In all the samples used, the Bartlett's tests yielded unambiguous ($p < 0.05$) information about the inequality of variances, which required the use of non-parametric tests. For this reason, Kruskal–Wallis tests were used to compare the average values of the samples and in those cases in which significant differences were detected, Wilcoxon pairwise tests were then carried out to identify the differences. The results were independently confirmed with the use of Mann–Whitney–Wilcoxon tests between samples.

All statistical analyses were carried out using R (www.r-project.org). Correlations were carried out through the non-parametric Spearman method, using robust regression (the 'rlm' R function). Graphs were created using the 'ggplot2' and 'gplot' R libraries. For correlations, graphical results of robust linear regressions were compared with those of a robust smoothed regression by fitting a smoother to the data, displaying both the smooth and the 95% confidence interval of its standard error. Multiple regression was carried out when simultaneously comparing how tool edge length and weight could correlate with processing time according to tool type. A principal component analysis was also carried out using the 'FactoMineR' library. Cut mark frequencies were also compared using Kruskal–Wallis tests and chi-square tests.

When analysing cut mark distribution, patterning in the samples was statistically approached by using the exact multinomial test (EMT), which is a goodness-of-fit test for discrete data. EMT provides an estimate of the probability that values in a vector occur patterned or randomly, under the assumption of an *ab initio* model. Such a model is created by providing each category with a theoretical probability that an item can fall into it. The resulting p-value yielded by the EMT is an estimate of the probability that an observed sample fits with the *ab initio* model, since the latter also contains a description of the degree of randomness in it. EMT calculates the exact probabilities of all possible outcomes of the contingency table that combines the number of cases and groups. In the present study, this was performed using the R library 'EMT' and the function 'multinomial.test'. In the present work, a Monte Carlo approach was used, because given the characteristics of the vectors used, the computation of the numerical calculation provided vectors of several gigabytes (GB). To enhance calculation, a workstation (Mountain) was used, which was provided with a RAM memory of 16 GB. The Monte Carlo approach simulates withdrawal of *n* samples of size *n* from the hypothetical distribution. The number of samples withdrawn from each calculation in the present analysis was 4 000 000. The *p*-value provided by this approach is the result of the addition of the relative frequencies of occurrence of outcomes that were less frequent than the outcome documented in the *ab initio* model.

For the present analysis, the *ab initio* model was defined as follows. Each bone was divided into five different sections: proximal epiphysis, proximal metadiaphysis, mid-shaft, distal metadiaphysis and distal epiphysis (see Yravedra and Domínguez-Rodrigo 2009). When significant results were documented because of the higher incidence of cut marks on shafts, the analysis was repeated on the most highly cut marked sections to determine whether orientation, rather than section type alone, had an influence on the cut mark patterning. Each section has four sides (anterior, posterior, medial and lateral), which are initially equally likely to receive a cut mark. Thus, the *ab initio* model considered equal probabilities of impact on five sections times four sides, with a resulting model of 20 parameters in the first EMT test, and one section (mid-shafts) times four sides, resulting in four parameters for the second EMT. Randomness was defined as cut marks evenly distributed among the 20 or four parameters according to the test. A patterned model was defined as cut marks showing some statistically significant occurrence on any of the sections/orientations of the original parameter set.

RESULTS

Processing time

The application of Bartlett's test showed that variances in the sample were unequal. Therefore, the use of non-parametric tests was required. A Kruskal–Wallis test showed that there were significant differences in the time of carcass processing with each tool set ($\chi^2 = 6.78$, $p = 0.0337$: see Table 1). Handaxes seem to butcher a carcass more efficiently. A pairwise Wilcoxon test shows that the significant difference is mostly the results of comparing average time values between handaxes and retouched flakes. It could be argued that if the sample sizes were bigger, handaxes would probably be even more significantly efficient than butchery performed with simple flakes, given the difference in absolute time between the two tool sets (Table 2). If only defleshing is considered, handaxes are substantially more efficient than simple and retouched flakes in absolute time values (Table 1), although pairwise tests do not show significant differences, probably due to the small sample size. Disarticulation showed similar absolute processing

Table 1 *The total amount of time during butchery, according to tool type, divided by butchery type: complete, defleshing and disarticulation*

	Complete butchery time (s)		*Defleshing time (s)*		*Disarticulation time (s)*	
	Total	*Mean/element*	*Total*	*Mean/element*	*Total*	*Mean/element*
Simple flake	10 188	268.10	7 264	382.31	2 924	153.89
Retouched flake	11 121	271.24	7 272	363.6	3 849	183.28
Handaxe	8 270	201.70	5 423	271.15	2 847	135.57

Table 2 *Wilcoxon pairwise tests showing the probability value of similar average processing time values between pairs of tool sets: significant differences appear in bold*

	Complete butchery		*Defleshing*		*Disarticulation*	
	Handaxe	*Retouched flake*	*Handaxe*	*Retouched flake*	*Handaxe*	*Retouched flake*
Retouched flake	**0.024**	–	0.079	–	0.260	–
Simple flake	0.295	0.356	0.168	0.593	0.76	0.76

Table 3 *The total amount of edge length and tool weight on the tools used during butchery, according to tool type*

	Edge length		*Tool weight*	
	Total	*Mean/tool*	*Total*	*Mean/tool*
Simple flake	1503.25	187.90	290	36.25
Retouched flake	1268.14	181.16	313	44.71
Handaxe	982.27	327.42	1594	531.33

Table 4 *Wilcoxon pairwise tests showing the probability value of similar average dimensional values between pairs of tool sets: significant differences appear in bold*

	Edge length		*Tool weight*	
	Handaxe	*Retouched flake*	*Handaxe*	*Retouched flake*
Retouched flake	**0.036**		**0.05**	
Simple flake	**0.036**	0.613	**0.05**	0.35

times when comparing handaxes and simple flakes, and no significant differences were detected among the three tool sets (Tables 1 and 2). From the point of view of time efficiency, handaxes seem to be the best of the three types of butchering tools used experimentally (Fig. 2 (a)).

Edge length and raw material mass

The null hypothesis of similar edge length in the three stone tool sets is rejected by a Kruskal–Wallis test ($\chi^2 = 7.3402$, $p = 0.0254$). Butchery with simple flakes required the largest edge length and butchery with handaxes the smallest (Table 3), as indicated by the significant pairwise differences when the latter were compared to simple and retouched flakes (Table 4) (Fig. 2 (c)).

A Kruskal–Wallis test also showed significant differences in mass among the tool types ($\chi^2 = 7.8004$, $p = 0.020$). Pairwise tests show that handaxes are significantly heavier than simple and retouched flakes, and the latter two show a similar mass (Table 4). Log transformation of the edge length and tool mass show a strong correlation (Figs 3 and 4) between these variables ($\rho = 0.869$, $p = 0.000$). This correlation is documented in simple flakes ($\rho = 0.862$, $p = 0.005$) and retouched flakes ($\rho = 0.892$, $p = 0.012$), but not in handaxes ($p = 0.330$), and is probably influenced by the small sample size ($n = 3$). In contrast, the correlation between edge length and processing time is not significant in simple flakes or handaxes ($p > 0.05$), but is significant in retouched flakes ($\rho = 0.928$, $p = 0.006$).

A multiple regression showed that processing time was not significantly influenced by either tool perimeter or tool weight when both were considered together ($R^2 = 0.16$, $p > 0.05$).

A principal component analysis showed a two-factor solution, which accounted for 98.15% of sample variance (first component = 64.34%; second component = 33.80%). The first component was determined by Perimeter and Weight (scores = 0.98 and 0.97, respectively). The second component was determined by Time (score = 0.99). All variables show positive and significant correlations ($p < 0.05$) with their dimensions. This shows that differences among the three tool sets are dimensional rather than in terms of processing time, supporting the results of the multiple regression analysis (Fig. 5).

In sum, if efficiency is considered as maximizing butchery through the investment of the minimum amount of raw material, it could be argued that simple and retouched flakes are more efficient for butchery than handaxes (Fig. 2).

Cut mark frequencies

Although some important differences in cut mark frequencies can be observed when comparing handaxes to retouched and simple flakes (Fig. 2 (b) and Table 5), a Kruskal–Wallis test suggests that these differences are not significant ($\chi^2 = 0.447$, $p = 0.799$). A chi-squared test also shows that no significant differences are appreciated when comparing cut mark frequencies per tool set and bone type ($\chi^2 = 1.706$, $p = 0.999$).

Cut mark patterns

Multinomial tests (EMT) show that the distribution of cut mark frequencies (Table 6) shows distinctive anatomical patterns that are statistically detectable (Table 7). All long bones show a significant pattern of cut mark locations ($p < 0.05$), which is conditioned by the higher clustering of cut marks on mid-shafts compared to the metadiaphyseal and epiphyseal sections (Table 6). When performing EMT on mid-shaft fragments alone, a significant patterning is also detected on every long bone (Table 7), showing that even on these sections, cut marks do not appear at random. When considering all shaft specimens, cut marks on humeri appear mostly on the cranial and lateral aspects of mid-shafts and on the distal metadiaphysis, preferably on the lateral and cranial sides. Cut marks on radii cluster more abundantly on the cranial and lateral aspects of mid-shafts (especially on the former) and on the cranial aspect of the proximal metadiaphysis. On femora, cut marks are predominant on the mid-shafts regardless of orientation. Cut marks on tibiae also cluster on mid-shafts, with a higher incidence on the cranial and caudal aspects, and to a lesser degree on the lateral aspect of the proximal metadiaphysis. Cut marks on metacarpals and metatarsals also appear more frequently on mid-shafts (due to skinning), with a smaller representation on the caudal sides.

This documented patterning on all long bones and their sections suggests that whatever the reasons that explain it (the ergonomics of stone tool butchery or the arrangement of muscle insertions on each bone, or a combination of both), the distribution of cut marks on long bones is not a random and completely stochastic process (Figs 6–8).

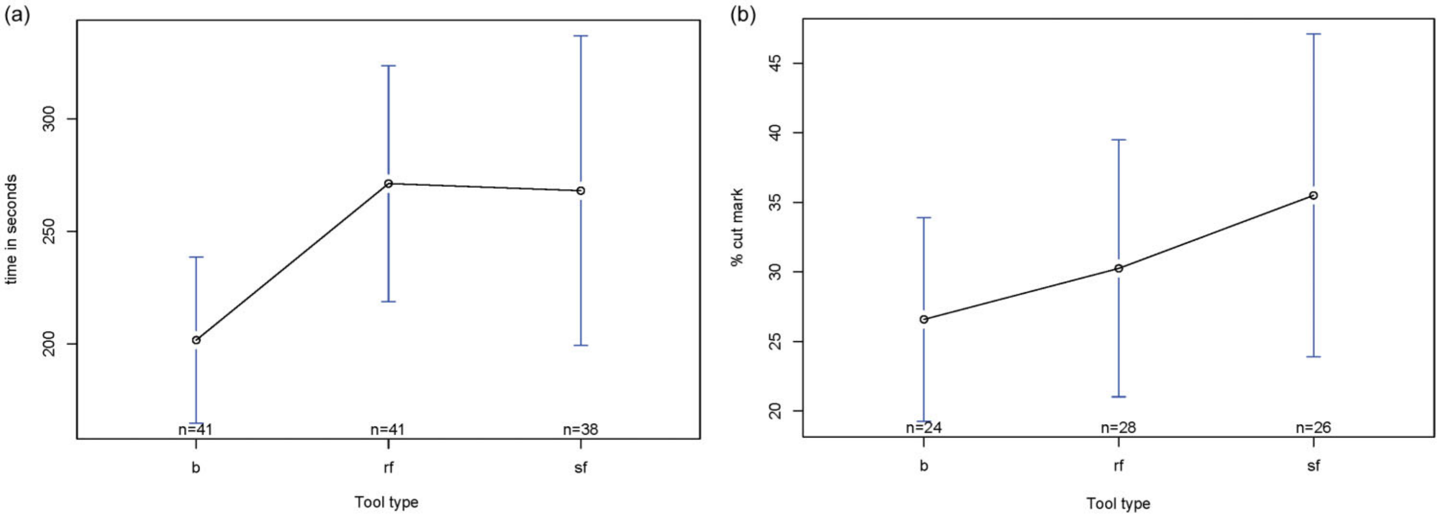

Figure 2 *Mean values and 95% confidence intervals for each tool type: (a) processing time; (b) cut mark frequencies; (c) edge length; (d) tool weight.*

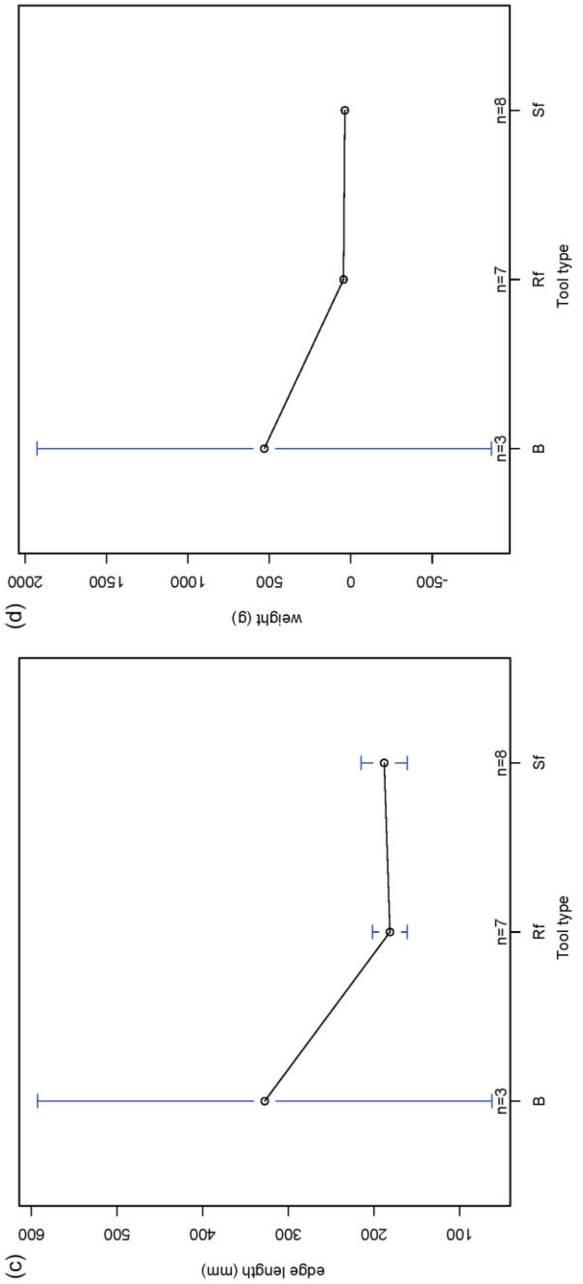

Figure 2 *Continued*

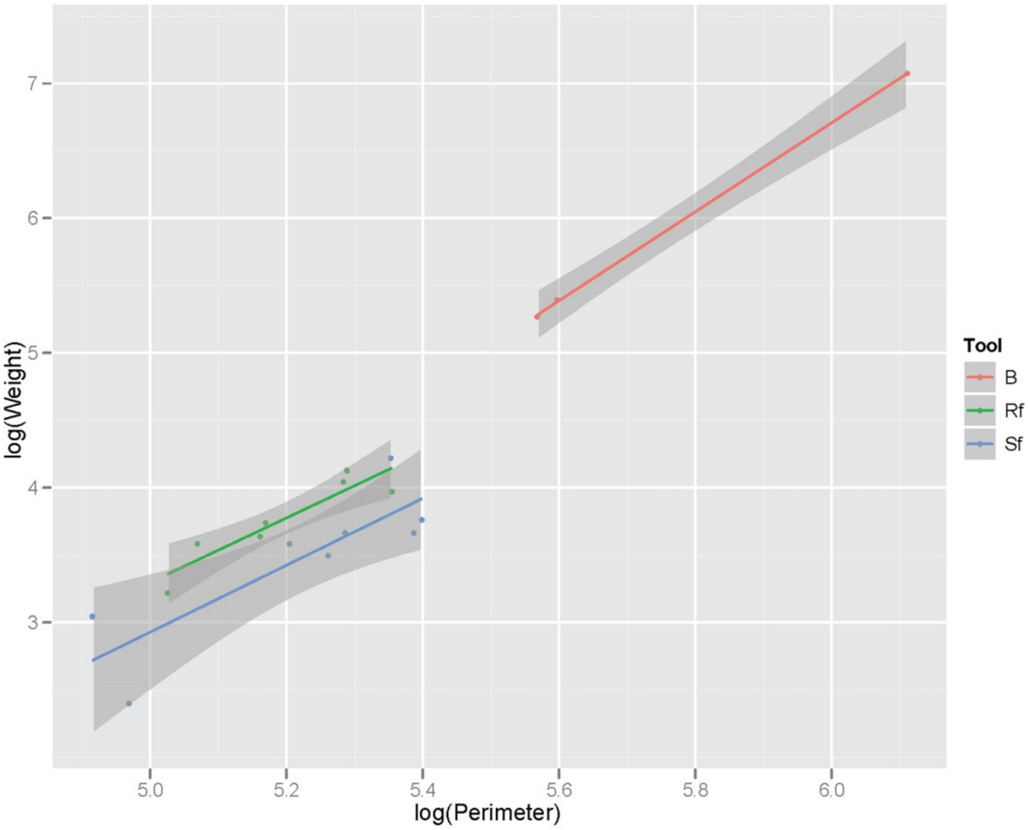

Figure 3 *Linear regression of log(weight) and log(edge perimeter) for each of the tools used.*

DISCUSSION

The ability to distinguish between actor, effector and trace (*sensu* Gifford-González 1991) is one of the main goals of taphonomic work. The present work has shown that some tool types are significantly more efficient during butchery than others. The use of an experienced butcher is a good proxy for patterns generated by prehistoric butchers; however, the modern butcher who performed the experiment was inexperienced in the use of stone tools. This may hinder the results presented here. Future research should include a larger number of experienced butchers in order to understand the variability in the results presented in this work. Provisionally, we regard the results as good, because the butcher claimed that he felt at ease using stone tools instead of metal tools.

Recent experimental work has provided compelling taphonomic arguments to effectively discriminate between metal and stone tool cut marks (Walker and Long 1977; Greenfield 2000, 2002), stone tool function (Walker 1978), trampling and cut marks and, within the latter, cut marks made with simple flakes, retouched flakes and handaxes (Bello and Soligo 2008; Bello *et al*. 2009; Domínguez-Rodrigo *et al*. 2009; de Juana *et al*. 2010).

Domínguez-Rodrigo *et al*. (2009) show that more than 90% of experimental marks could be correctly classified as trampling marks or cut marks when considering a determined set of

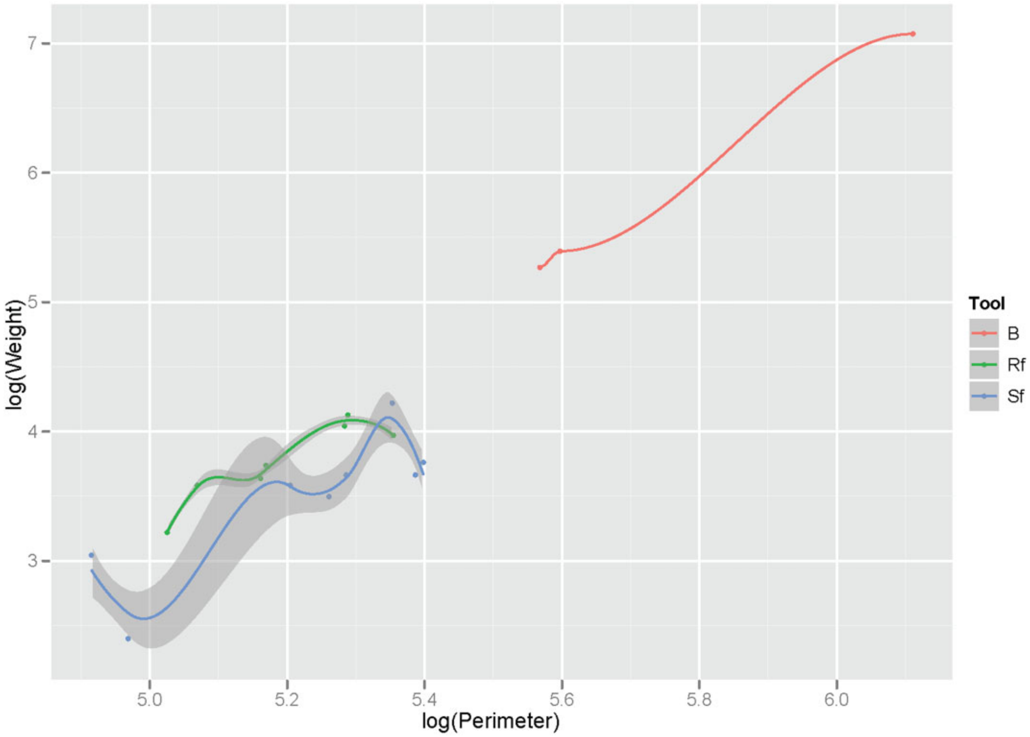

Figure 4 *Polynomial regression with a loess smoother of log(weight) and log(edge perimeter) for each of the tools used.*

categorical variables. Differentiation between cut marks made with simple and retouched flakes was also successful, and even in 80% of the cases experimental cut marks from retouched flakes could be differentiated from those made with handaxes (de Juana *et al*. 2010). Retouched flakes show a less straight outline of the edge than simple flakes, and for this reason the area of contact with the bone surface comprised by the width of the tool edge is wider, resulting in broader grooves. The irregular edge also accounts for the occurrence of striations parallel to the main groove (shoulder effect), which may be multiple, showing—as a typically diagnostic characteristic—that in some cases, their depth is similar to that of the main groove. This contrasts with the much shallower (and frequently irregular) shoulder effect generally observable in trampling marks. Also, this irregular (sometimes serrated) profile of the edge creates a particular morphology in the resulting cut mark, since the flake is commonly used in an up-and-down swinging motion, thus making some lateral part of the flake edge (produced by retouch) touch the surface before the remaining edge. This frequently produces one or more grooves that intersect with the main groove in the form of oblique grooves or a fork. The difference between this situation and the oblique striations that intersect trampling marks caused by sediment abrasion lies in the depth of the former, which—as in the case of the shoulder effect—are deeper than those documented in trampling marks, and are similar in depth to that of the main groove (Domínguez-Rodrigo *et al*. 2009).

Cut marks made with handaxes are very broad and comparatively shallow in proportion. They are characterized by a _/-shaped or trapezium-shaped section, the base of which is horizontal, the groove being wider than it is deep. They also show the shoulder effect, and extensive flaking very

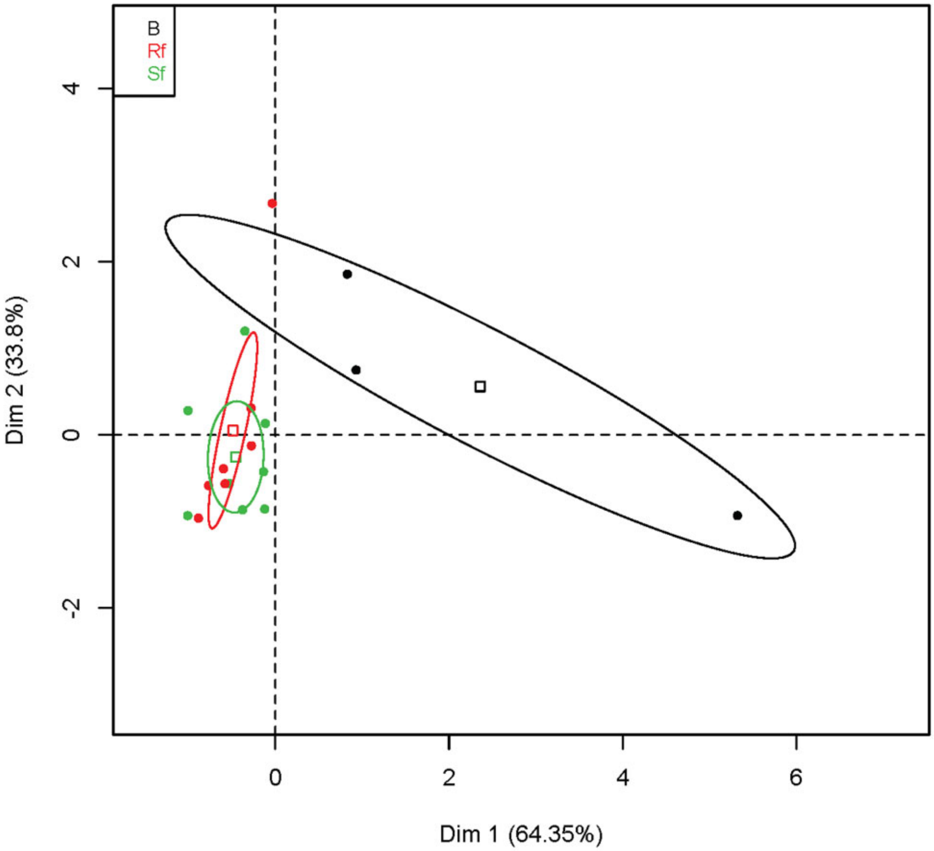

Figure 5 *PCA of the three tool sets, showing ellipses displaying the 95% confidence intervals. Note the clear separation of handaxes from simple and retouched flakes.*

Table 5 *The number of cut marks per carcass according to tool type*

	Tool type	*Number of cut marks*	*Total*
Carcass 1	Simple flakes	438	923
Carcass 2	Simple flakes	485	
Carcass 3	Retouched flakes	597	847
Carcass 4	Retouched flakes	250	
Carcass 5	Handaxes	418	638
Carcass 6	Handaxes	220	

frequently occurs on the shoulder edge. This contrasts with the V-shaped section of cut marks made with simple flakes, with less flaking on the shoulder (Domínguez-Rodrigo *et al*. 2009). Greenfield (1999, 2005) documented that retouched flakes (scrapers) also show a morphological pattern similar to that reported for marks made with metal knives with serrated edges. Cut marks made with handaxes show a high frequency of multiple and fork-shaped marks (>95%), with a

Table 6 *Number of cut marks per element and section according to orientation*

		Number of cut marks			
		Cranial	*Caudal*	*Medial*	*Lateral*
Humerus	Prox. epiphysis (1)	3	2	1	1
	Prox. metaphysis (2)	18	1	9	19
	Diaphysis (3)	74	25	36	68
	Distal metaphysis (4)	54	44	88	61
	Distal epiphysis (5)	18	0	28	28
Radius	Prox. epiphysis (1)	32	2	14	16
	Prox. metaphysis (2)	59	4	20	14
	Diaphysis (3)	70	11	14	34
	Distal metaphysis (4)	3	1	0	0
	Distal epiphysis (5)	0	0	0	0
Femur	Prox. epiphysis (1)	7	0	0	2
	Prox. metaphysis (2)	22	12	5	64
	Diaphysis (3)	94	103	69	120
	Distal metaphysis (4)	7	47	29	9
	Distal epiphysis (5)	9	12	26	22
Tibia	Prox. epiphysis (1)	0	0	0	0
	Prox. metaphysis (2)	0	28	0	43
	Diaphysis (3)	106	132	23	108
	Distal metaphysis (4)	0	0	0	0
	Distal epiphysis (5)	6	3	4	0
Metacarpal	Prox. epiphysis (1)	0	0	3	3
	Prox. metaphysis (2)	1	5	22	6
	Diaphysis (3)	7	0	32	26
	Distal metaphysis (4)	0	0	0	0
	Distal epiphysis (5)	0	0	0	0
Metatarsal	Prox. epiphysis (1)	0	0	0	6
	Prox. metaphysis (2)	3	0	4	1
	Diaphysis (3)	34	0	34	10
	Distal metaphysis (4)	0	0	0	0
	Distal epiphysis (5)	0	0	0	0

Table 7 P *values of the EMT for each long bone according to all sections (epiphyseal, metadiaphyseal and mid-diaphyseal) and to mid-shaft sections alone*

	All sections	*Mid-shafts*
Humerus	0.000	0.002
Radius	0.000	0.000
Metacarpal	0.000	0.000
Femur	0.000	0.004
Tibia	0.000	0.000
Metatarsal	0.000	0.000

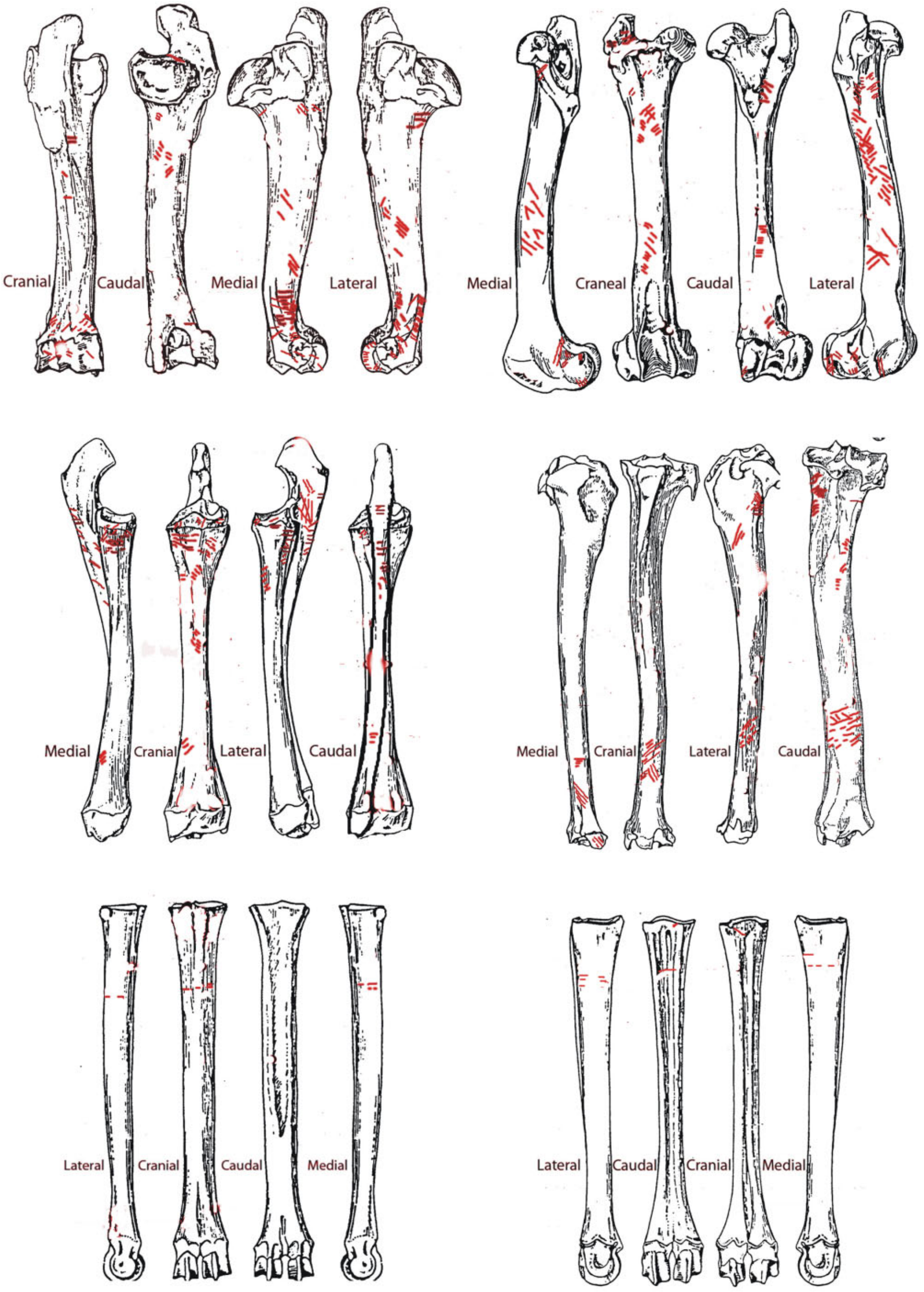

Figure 6 *The cut mark distribution on each of the six long bone types resulting from the use of simple flakes (see online for a colour version of this figure).*

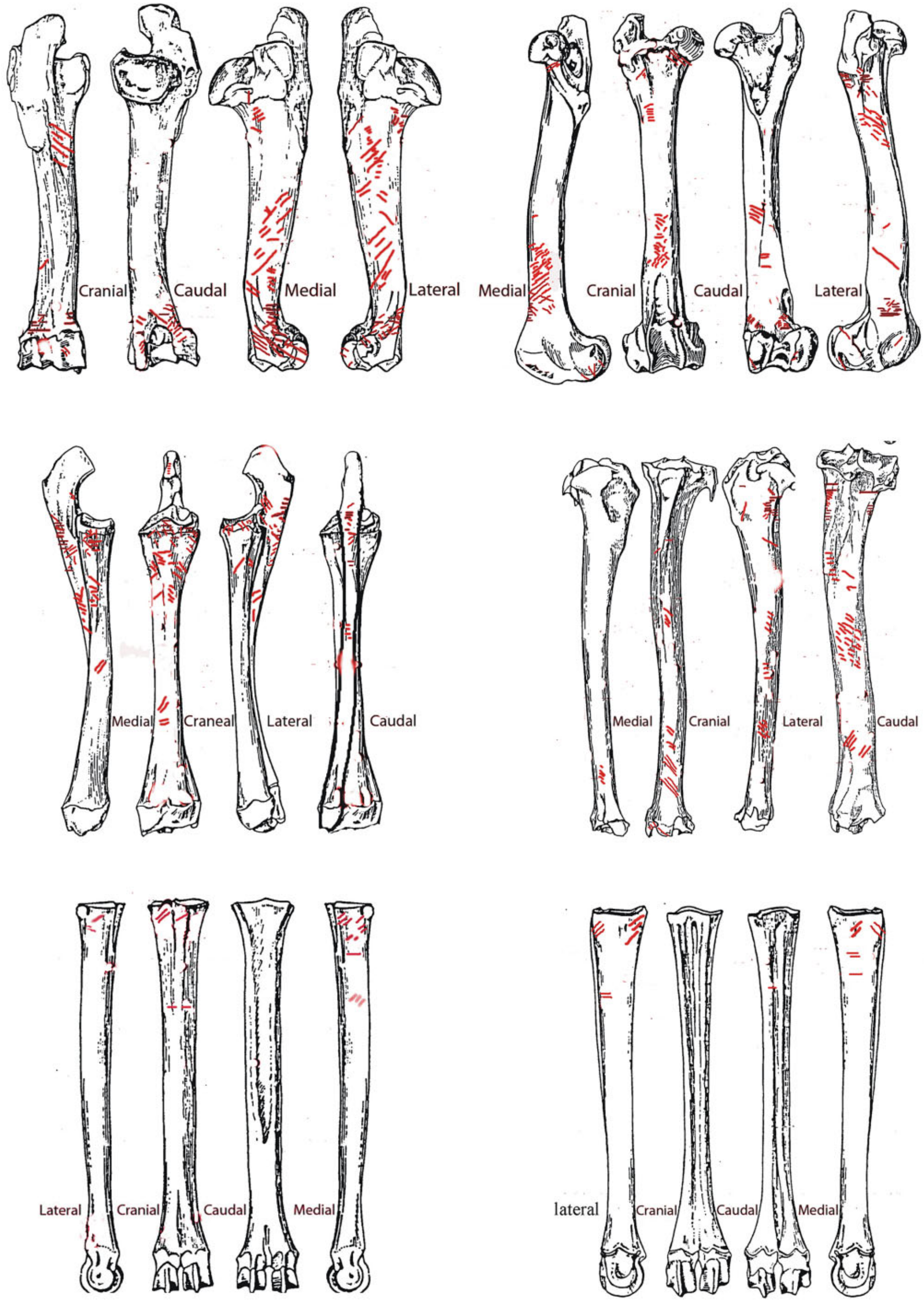

Figure 7 *The cut mark distribution on each of the six long bone types resulting from the use of retouched flakes (see online for a colour version of this figure).*

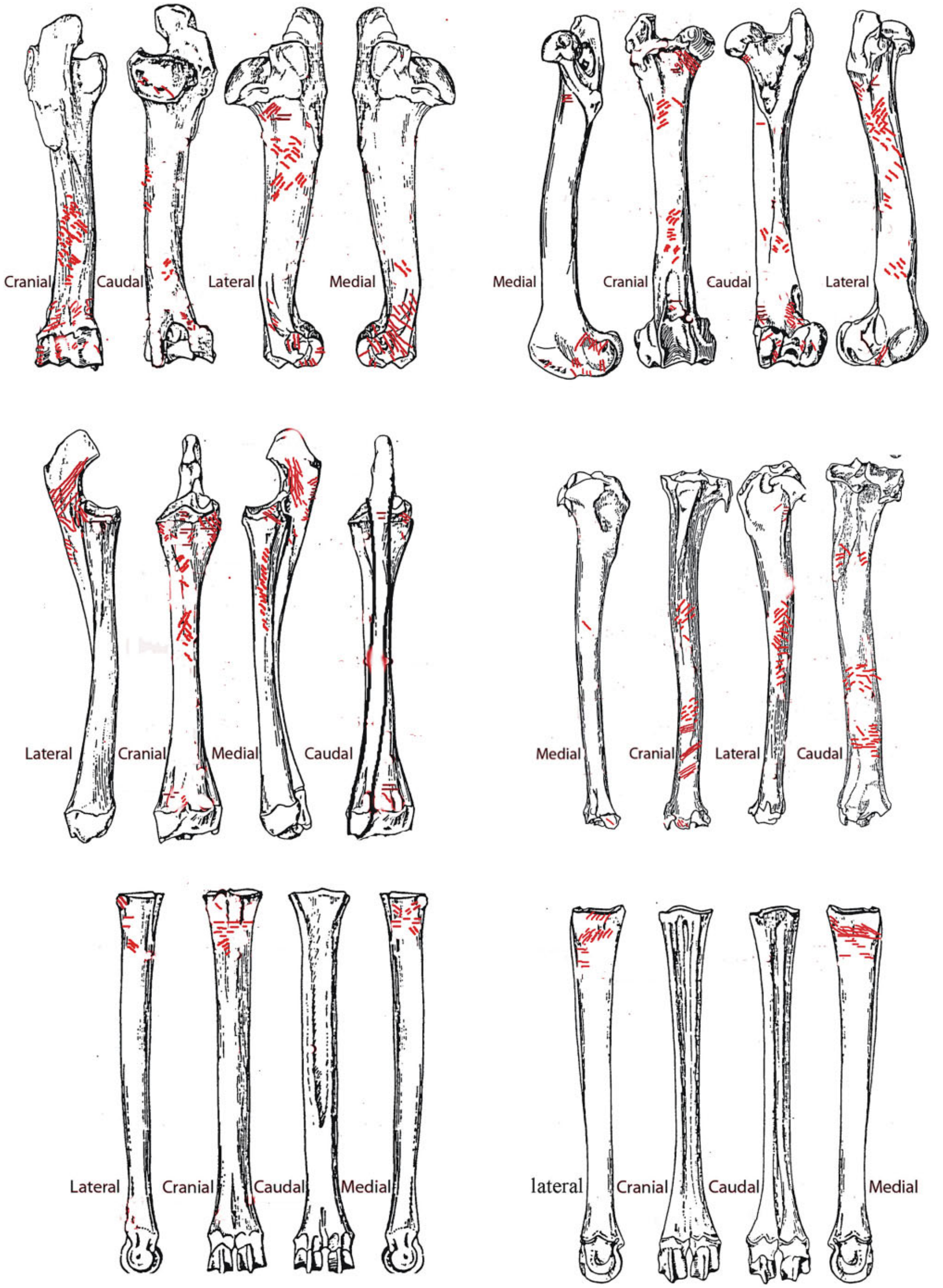

Figure 8 *The cut mark distribution on each of the six long bone types resulting from the use of handaxes (see online for a colour version of this figure).*

higher number of multiple marks (which in cut marks made with retouched flakes average <2 [mean = 1.01] and for handaxes 3 or higher [mean = 3.1] per cut mark) and of fork-shaped marks (cut marks made with retouched flakes average <1 [mean = 0.6] and for handaxes 3 or higher [mean = 2.99] per cut mark). Flaking and the shoulder effect are also more frequently represented in marks made with handaxes (50% more) than in cut marks resulting from the use of retouched flakes (de Juana *et al.* 2010). Future research should analyse how the distinctive shape of cut marks created with various tools is modified by the time of use of each tool type. Presumably, the diagnostic features resulting from sharp edges that can be statistically used to discern tool types could become more ambiguous as the tool edge is modified through use.

Several authors have differentiated types of marks and tools, evaluating categorical variables (Walker and Long 1977; Walker 1978; Greenfield 2000, 2002, 2005; Bello and Soligo 2008; Bello *et al.* 2009; Domínguez-Rodrigo *et al.* 2009). A critique of this confidence in discriminating between tool types by using cut marks has recently been presented by Merritt (2012), based on the slight misconception that the bulk of these interpretations are based on cut mark size, which can potentially be confounded by an array of elements during the butchery process. Merritt (2012) did not address one of his stated goals, that skeletal location affects mark morphology, since he did not carry out a morphological study of cut marks, but simply made a dimensional analysis of marks created with cores and simple flakes. This novel approach is welcome, because it can show how element types and different butchering behaviours (skinning, disarticulation and defleshing) can affect the dimensional properties of marks, but this approach should not be confounded with a morphological or even morphometric analysis of cut marks.

In his analysis, Merritt (2012) discovered that mark sizes overlapped between cores and flakes, which is not unexpected given some methodological shortcomings. First, the tools were not retouched and in most cases a single tool was used for the complete butchery. Since the core edges and flakes presented no retouch, no dimensional differences should be expected, as documented between marks created by simple and retouched flakes (Domínguez-Rodrigo *et al.* 2009; de Juana *et al.* 2010), other than those due to differences in edge angle. Second, Merritt's sample included low- and high-angled flakes, which contributed to create dimensional overlap between marks created by cores and flakes. When a single flake was used for the whole butchery process, the blunting of the edge may have potentially created larger marks than the original sharp edge. Merritt argued that a cluster of slices is counted as a single cut mark by some authors (e.g., de Juana *et al.* 2010), but his study counted each distinct V-shaped striation with internal microstriae as a single cut mark. This may not be accurate, since what was counted by de Juana *et al.* (2010) as a single cut mark was the result of marks with variable dimensional properties created during a single controlled slicing motion by the tool, not those resulting from a cluster of slices. By counting the multiple mark pattern created by individual slices as separate cut marks, Merritt's approach is overemphasizing the number of marks created by cores and flakes, probably contributing to their potential equifinality. Despite these methodological shortcomings, Merritt (2012) documents that the core cut marks sample has a significantly wider median edge angle than the flake sample, and that this is reflected in a significantly larger median cut mark width and depth in the core tool sample compared to the flake tool sample, which is reflected not only in the differences in median values but in the frequency of the wide and deep marks created by the two tool types. Therefore, even from a dimensional point of view, statistical differences are observed between marks created by cores and flakes. What Merritt's data shows is that individual marks cannot be attributed to specific tools on the basis of dimensional criteria alone (overlap in boxplots), but tool attribution can be better supported dimensionally at the assemblage level when considering central values of the complete mark samples.

The taphonomic morphological arguments that were used in a combination of over one dozen variables covering several micro-characters of marks can potentially be used to infer the effector (stone tool type), thus providing an empirical basis for distinguishing when flakes (simple or retouched) and handaxes may have been used for butchery in the archaeological record (Bello *et al.* 2009; Yravedra *et al.* 2010). This is where the present study becomes relevant, since butchery with different stone tool types can be taphonomically addressed, and optimal foraging approaches to butchery, stone tool use and curation can be developed and discussed.

Traditionally, it has been experimentally shown that simple flakes can be extremely efficient tools for butchery of even large-sized animals (Schick and Toth 1993). In their experiments, Schick and Toth (1993, 166) noticed that simple flakes needed to be replaced or their edge resharpened 5–10 minutes after first use, while the duration was longer for a retouched flake. However, in the present experiment, some simple flakes were replaced in 1 hour—or in the case of retouched flakes, they were replaced or resharpened after more than 1 hour of use. Several researchers (e.g., Schick and Toth 1993; Gorman and Mitchell 1995; Mitchell 1996; Domínguez-Rodrigo *et al.* 2001), despite providing diverse interpretations for handaxe functionality, agree that these tools can be apt for butchery.

The present study has shown that small-sized handaxes can be more efficiently used for butchery than flakes. This does not mean that all handaxe types are equally functional for butchery. The large handaxes typical of the ESA Acheulian do not seem to be as efficient for butchery as the small handaxes used here, because of their larger size and more difficult handling and their less acute edges, which make them less sharp than is desirable for proper cutting through flesh. This can partially explain why no clear functional relationship has been found between handaxes and butchery during the Early Pleistocene, either because most early Acheulian sites lack associated fauna or because when functional analyses have been carried out, micro-residues show that these tools were used for a different type of activity (e.g., Domínguez-Rodrigo *et al.* 2001). In contrast, with relation to the second half of the middle Pleistocene, use-wear analyses on small handaxes has yielded unambiguous evidence of meat polish produced during butchery (Keeley 1980; Mitchell 1998; Ollé 2005; Ollé *et al.* 2010). When and why hominins started using handaxes for butchery remains an intriguing question. Olorgesailie is known for its abundance of handaxes and the occurrence of sparse faunal remains (Isaac 1977). Shipman *et al.* (1981) suggested that butchery of baboons had taken place at this Acheulian site, although no solid taphonomic indication thereof has been documented on the faunal remains. The archaeology shows that throughout the Pleistocene, flakes never ceased to be the main butchery tools. If handaxes are more efficient in terms of time for the butchering of carcasses, their infrequent use in the past for butchery could be due to the offset in cost introduced by raw material use and curation, as hinted by the present study. Counter to this argument, it could be argued that since handaxes could be continously resharpened over substantially longer periods of time than flakes, handaxes could also be efficient tools from the point of view of raw material use. This remains a topic to be addressed in future experimental work. If such work ends up demonstrating that raw material curation has a smaller impact in butchery decisions, then the scarcity of evidence of hominins using handaxes for butchery during the Pleistocene could be due to either this evidence remaining taphonomally unnoticed or to hominin behaviour not being as reductionist as optimal foraging approaches like to think.

A corollary to the experimental work presented here is that the cut mark patterns created by the three different tool sets do not differ when the butcher is the same. In addition, the occurrences of cut marks on long bones seem to be patterned, in contrast with assumptions that cut mark patterns are purportedly stochastic in nature. Recently, it has been shown that bone breakage behaviours that are culturally induced produce patterned anatomical distributions of percussion notches and that defleshing also produces anatomical patterns of cut mark location (Blasco *et al*. 2013). The present study provides more supportive evidence that cut marks are not stochastic taphonomic modifications, and that their anatomical location is more tightly linked to butchery behaviour than anticipated.

CONCLUSIONS

Handaxes constitute a source of plural interpretations with regard to their role in the adaptation, technology and behaviour of early hominins (e.g., Soressi and Hays 2003). The present experimental work has shown that small handaxes provide higher return rates in butchery activities than simple and retouched flakes. Efficiency (measured in time) is prominent in handaxes when defleshing, over and above other types of butchering activity. In contrast, in the case of disarticulation, when the three stone tool sets (simple flakes, retouched flakes and handaxes) are compared, the return values obtained are very similar. The experiments described in the present work also show that the cut mark distribution is patterned and that the three types of tools generate similar cut mark patterns. Simple flakes may be a more efficient way to butcher a carcass in terms of raw use material (a smaller mass of raw material is needed to butcher a carcass than when using handaxes), although handaxe resharpening could offset this potential advantage.

Jones (1980) and Mitchell (1996) noticed in their experimental work that handaxes were effective tools for butchery, but this interpretation was rather descriptive, based on their impressions during butchery. Machin *et al*. (2005, 2007) provided convincing quantitative evidence that handaxes were indeed very efficient butchery tools and that the sharpness of the edges had more influence in tool efficiency than symmetry. The present experimental study provides some controlled background to support Jones' (1980, 1994), Mitchell's (1996) and Machin *et al*.'s (2005, 2007) interpretations. When analysing if there was any correlation between edge length and stone tool weight, comparing these with their effectiveness during butchery, we have reported that there are no significant differences between these variables. Therefore, we can only consider the efficiency of stone tools using these variables from the point of view of curation of the raw material. In this case the use of simple or retouched flakes being better than handaxes, since butchery thus performed requires a smaller amount of raw material. However, as mentioned above, future experimental series should attempt to test efficiency in terms of tool duration and total raw material used, in order to test the latter interpretation.

Our study also shows that cut marks do not occur at random and are less stochastic than previously assumed. Defleshing leaves a preferential cluster of cut marks on mid-shafts from long bones, and even on these sections, depending on the element type, patterns are statistically demonstrable.

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A biometric analysis of the pelvic acetabulum as an indicator of sex in bovids

Analyse biométrique de l'acetabulum pelvien en tant qu'indicateur du sexe chez les bovidés

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ABSTRACT

Despite its potential importance in the reconstruction of hunting strategies and subsistence patterns, determining sex in zooarchaeological assemblages is a task that has been often neglected because the assemblages consist mainly of fragmentary bones. Only a limited amount of research has been focused on sexing individuals at archaeological sites. Although dimorphic elements in skeletal anatomy (e.g., horns) are the most widely used indicators for sexing, other skeletal parts, such as the pelvic acetabulum provide valuable information to identify sex. The present work builds upon previous research and indicates the most useful indicators in the pelvic acetabulum to distinguish sex in bovids, with the goal of providing an analytical basis to expand interpretations of carcass acquisition strategies by humans.

RÉSUMÉ

En dépit de son importance potentielle dans la reconstitution des stratégies de chasse et des systèmes de subsistance, la détermination du sexe dans les assemblages zooarchéologiques a souvent été négligée, en raison de la nature fragmentaire des assemblages d'os. Seule une partie limitée de la recherche a été focalisée sur la détermination du sexe des individus sur les sites archéologiques. Bien que la présence d'éléments dimorphes dans l'anatomie du squelette (par exemple les cornes) ait été largement utilisée dans la détermination du sexe, certaines parties du squelette apportent des informations très valables en la matière. L'une des plus importantes est l'acetabulum pelvien. Le présent travail est construit à partir d'une recherche antérieure et met en évidence les indicateurs les plus utiles dans l'acetabulum pelvien pour la détermination du sexe chez les bovidés, dans le but de fournir une base analytique pour élargir l'interprétation des stratégies d'acquisition des carcasses par l'Homme.

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1. Introduction

Sex identification of animals accumulated in archaeofaunal assemblages is a potentially useful tool for the reconstruction of hunting strategies and subsistence of prehistoric human groups (Arceredillo et al., 2011; Davis et al., 2012; Greenfield, 2002; Munro et al., 2011; Weinstock, 2000). The difficulties of sexing fragmented archaeofaunal collections have often been stressed in zooarchaeological studies (e.g., Klein and Cruz-Uribe, 1984; Munro et al., 2011). The main reason for this is the state of fragmentation in which archaeologists find faunal remains, or the absence of diagnostic elements. Sexing is possible through particular traits or morphological features (e.g., antlers in cervids, horns in bovids, the presence or absence of canines in equids, the presence of a baculum in carnivores) or the pelvis shape (Davis, 1987; Greenfield, 2002; Klein and Cruz-Uribe, 1984; Munro et al., 2011; Ruscillo, 2003). In addition, sexing can also be approached through the biometrics of certain skeletal parts, such as metapodials.

Sexing archaeofaunal remains could play a major role in the reconstruction of subsistence patterns and hunting strategies by early hominins. Certain carnivores show particular preferences when preying on different taxa. The spotted hyena, for example, displays a preference for males in the case of wildebeests, with a sex ratio of 1.84:1 in the Seregeti (Kruuk, 1972); this is also documented when they prey on Thomson's gazelles (ratio = 3.1:1) (Kruuk, 1972). In contrast, spotted hyenas prefer females when they kill zebras (0.5:1 Seregeti; 0.4:1 Ngorongoro) (Kruuk, 1972), showing that they can be selective hunters.

Lions also prefer males when they kill wildebeest (2:1) in the Serengeti (Schaller, 1974). They show no sex preference when killing zebras and buffalos (1:1), except with older individuals, in which case males are hunted more frequently. In the case of Thomson's gazelle, lions prey on one sex or another depending on the season (Schaller, 1974).

Leopards especially prey on male Thomson's gazelles (73%), but they prefer females when they kill reedbucks in the Serengeti (Schaller, 1974). Cheetahs show no sex preference when they prey on Thomson's gazelle in the Serengeti, but, in contrast to lions, they prey more on females when they hunt older individuals (Schaller, 1974). Wild dogs also show preferences for male Thomson's gazelles (Schaller, 1974).

These few examples show that carnivores are selective hunters when it comes to the sex of the prey. They have preferences among species and frequently display preferences of one prey sex over the other depending on each species (Kruuk, 1972; Mills, 1990; Schaller, 1974). Potential scavenging hominins should display a selection of prey sex coincident with those of the carnivores that they scavenge from. Archaeological examples of sex selection or the lack thereof abound in the zooarchaeological literature. For example, Arceredillo et al. (2011) observed that Neanderthal groups killed more males than females of chamois at the site of Valdegoba (Burgos, Spain). In contrast, Weinstock (2000) concluded that because males and female reindeer were equally hunted at the site of Stellmoor (northern Germany), the groups at this site practiced non-selective hunting.

Sexing specific taxa have been carried out using biometric features (e.g., Arceredillo et al., 2011; D′Errico and Vanhaeren, 2002; Greenfield, 2002; Munro et al., 2011; Tchernov et al., 1990; Weinstock, 2000), statistical methods (e.g., Arceredillo et al., 2011), discrete traits (e.g., D′Errico and Vanhaeren, 2002; Munro et al., 2011; Prummel and Frisch, 1986; Ruscillo, 2003), or using DNA analysis (McGrory et al., 2012, Svensson et al., 2008). Munro et al. (2011) provided a list of traits to distinguish the sex for *Gazella gazella* (mountain gazelle) using traits such as the atlas, whose caudal wings are more robust in males than females; the body, being broader and higher in males than females; the glenoid cavity of the scapula, ovoid in females and round in males; and the pubic symphysis, where the pubic arch is V-shaped in males and U-shaped in females. D′Errico and Vanhaeren (2002) differentiated between red deer males and females through morphological and metrical variables taken from canines. Svensson et al. (2008) and McGrory et al. (2012) analyzed DNA from cattle metacarpals and mandibles, respectively, in order to separate sexes. Prummel and Frisch (1986) proposed how to differentiate male and female sheep through differential pelvic morphology. Greenfield (2002) used different measurements from the acetabulum to determine the sex of cervids and bovids, and some of these characters constitute the bulk of the present study.

The innominate is one of the best indicators of sex in mammals due to the effects of reproduction upon the skeletal structure (Greenfield, 2002). The medial faces of the iliac and the pubic areas have several diagnostic traits that are very useful to determine sex from complete or partially complete specimens (Greenfield, 2002). One of the most important diagnostic characters is the medial wall of the acetabulum, which is thinner and shorter in females and higher and more robust in males. As Greenfield (2002) noticed, this feature was addressed early in both German and English literature (Boessneck et al., 1964; Grigson, 1982; Lemppenau, 1964; Prummel and Frish, 1986; Von Leithner, 1927). However, other acetabular features have been neglected in the literature (Greenfield, 2002).

The aim of the present study is to test the characters used by Greenfield (2002) to determine sex on a wider array of bovid taxa. It will be shown that the sex of individual carcasses can be confidently obtained through several types of measurements of the pelvic acetabulum.

2. Sample and method

The specimens included in the present study belong to adult African bovids. Initially, the goal was to obtain the measurements of as many modern African bovids as possible. However, because of sample size (i.e., limited number of individuals per taxon) and also because portions of the bovid collections curated at museums are not properly sexed (see also Greenfield, 2002), we could only test Greenfield's (2002) diagnostic acetabular characters on a total of eight African bovid taxa. The sample was composed of 109 individuals, including a total of 172 acetabula. This number results from the presence of some incomplete innominates in the collection. Both sides of the pelvis were measured (when available) to account for potential asymmetry (see Lyman, 2006). All the acetabula were equally measured; that is, all variables as described below were taken.

The species included in this study were: *G. dorcas* (dorcas gazelle), *G. granti* (Grant's gazelle) among Antilopini; *Alcelaphus buselaphus* (hartebeest) among Alcelaphini; *Tragelaphus strepsiceros* (Kudu), *Taurotragus oryx* (eland), and *Tragelaphus scriptus* (bushbuck) among Tragelaphini; *Aepycerus melampus* (impala) among Aepycerotini; and *Kobus ellipsiprymnus* (waterbuck) among Reduncini (Table 1). All the individuals measured were adults.

Measurements were collected on specimens from the zoology collections of the Natural History Museum of London and the "Museum national d'histoire naturelle" of Paris. Measurements were taken with digital calipers.

For the present study, eight measurements were taken. Three of them were suggested by Greenfield (2002), two by Von den Driesch (1976) and the remaining three are proposed by the authors. They are described below (Fig. 1):

Table 1
List of taxa in which the analysis was conducted, showing the number of specimens and sex.
Tableau 1
Liste des taxons dans lesquels l'analyse a été effectuée, montrant le nombre de spécimens et le sexe.

Species	Total acetabulae	Sex
Aepycerus melampus	13	Male
Aepycerus melampus	16	Female
Alcelaphus buselaphus	10	Male
Alcelaphus buselaphus	8	Female
Gazella dorcas	13	Male
Gazella dorcas	8	Female
Gazella granti	13	Male
Gazella granti	6	Female
Kobus ellipsiprymnus	8	Male
Kobus ellipsiprymnus	8	Female
Taurotragus oryx	8	Male
Taurotragus oryx	6	Female
Tragelaphus scriptus	22	Male
Tragelaphus scriptus	20	Female
Tragelaphus strepsiceros	6	Male
Tragelaphus strepsiceros	6	Female
Total	171	

H1: the height of the medial wall of the acetabulum (Greenfield, 2002). The arms of the caliper must be placed above and below the medial wall in the centre of the acetabulum, pressing to ensure that the arms do not move and thus avoiding mistakes when the measurement is taken. One arm of the caliper is resting internally on the acetabular surface (Fig. 1) (see further examples in Greenfield, 2002).

H2: the height of the acetabular medial wall (Greenfield, 2002). This measurement is taken by placing the arms of the caliper on both edges of the wall, in the midsection of the wall. In this case, the upper arm of the caliper does not rest inside the articular surface of the acetabulum (see Fig. 1). H2 is one of the most objective and reliable measurements because the arms of the caliper stand on both edges of the wall, avoiding deviation.

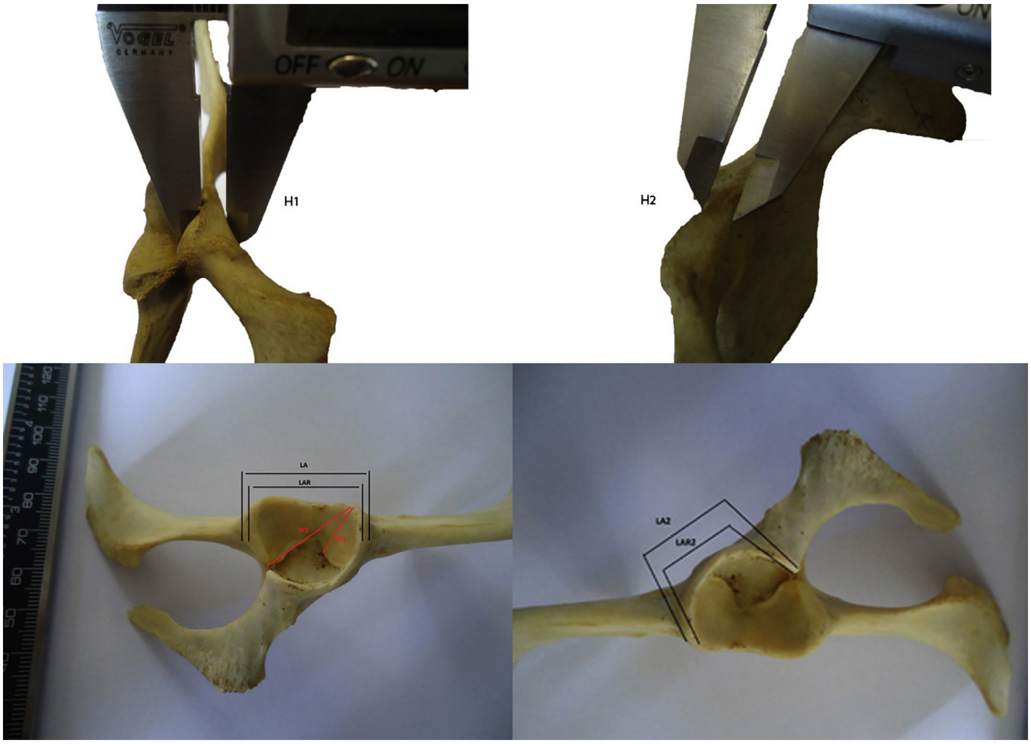

Fig. 1. (Color online.) Examples of how to take the measurements described in the present work. See description Methods section of text.

Fig. 1. (Couleur en ligne.) Exemples de la manière dont sont prises les mesures dans la présente étude. Voir le paragraphe « Description des méthodes » dans le texte.

LA: the length of the acetabulum including the lip (Greenfield, 2002; Von den Driesch, 1976). It is taken from the lateral face of the acetabulum. According to Von den Driesch (1976), this measurement is not recommended for species that have no lip in the acetabulum.

LAR: the internal length of the acetabulum from the lateral side (Greenfield, 2002; Von den Driesch, 1976). Its use is recommended for species that have no lip in the acetablum (Von den Driesch, 1976).

W1 (Greenfield, 2002) and W2 (the authors): the width of the acetabulum. It is taken from the edge of the acetabular rim to the end of the incisura acetabular. For open acetabula, both measurements are taken. However, for closed acetatulae only W2 is taken. In this case, it is not possible to take W1 because one of the arms of the caliper cannot be placed.

Some additional variables have been added to the study:

LA2: external length of the acetabulum. It is taken from the medial side, including the lip.

LAR2: internal length of the acetabulum. It is also taken from the medial side.

H1_LA, H1_LA2, H1_LAR, H1_LAR2: These are ratios between different length variables as described above and the thickness of the medial wall of the acetabulum, also as described above.

H2_LA, H2_LA2, H2_LAR, H2_LAR2: These are ratios between different length variables as described above and the external height of the acetabular wall.

2.1. *Statistical method*

A principal component analysis (PCA) was carried out using the "FactoMineR" library of R (www.r-project.org). Variables were scaled prior to analysis. Given the high portion of sample variance explained, a two-component solution was selected. The PCA aimed at differentiating the sex of each case within a Euclidean space. A comparative analysis of the scores provided by the eight taxa was also undertaken in order to conclude whether sex differentiation was effectively made regardless of taxon.

Once the variables that more effectively determined sex were identified, a logistic regression (LR) was carried out to determine the ratio of these variables that discriminated between male and female acetabular morphology. This was done by using a general linear model (GLM) using a binomial family. The procedure was carried out by a stepwise removal of variables according to their significance in the final solution and the percentage of sample variance explained (adjusted R2).

3. Results

A PCA yielded a two-component solution, in which > 97% of the sample variance was explained. The first component explained most of the inertia (85.25%), compared to the second component (11.95%). The alpha bags (i.e., confidence ellipses) showed no overlap in the 95% confidence intervals of the male and female subsamples (Fig. 2). When the sample was displayed according to taxon, a complete overlap was observed, which documents that the sex separation provided by the variables used is not dependent on species or body size. As can be seen in Fig. 2, the confidence ellipses of all taxa overlap, showing that although a slight allometry is identified in *Taurotragus oryx*, the rest of taxa overlap significantly. Thus, large animals such as *Tragelaphus strepsicerus* overlap with a large portion of the *Aepycerus melampus* sample. Furthermore, beyond the boundaries of the confidence intervals, individual data from the smaller *Tragelaphus scriptus* overlap with the whole range of the spread of the large-sized *Taurotragus oryx* data and display an even wider range on the first component. Therefore, variation in size is not reflected on the first component, with small and large taxa showing similar positions along its range. If anything, size seems to be more discriminant on the second component (which only explains 11.95% of the sample variance) and even here, the separation of taxa is minimal, with all taxa clustering around the axes of both components.

The ratio variables displayed a higher loading score than the traditional acetabular variables. This indicated a wider morphological variability in the shape and dimensions of acetabula, when using the complete taxonomic sample, and also indicates that the best approximation to differentiating sex is to use a proportion of the acetabular wall height and its length, which effectively overcomes this variability. H2_LA2 (0.9366) and H2_LA (0.9363) are the two variables that best determine the first component, with a correlation score > 0.9, followed by the other ratio variables. Loading scores for the second component are more evenly divided among all the variables, with H2 showing the highest score (0.4) and the other variables ranging from 0.34 to 0.37 (Table 2).

The PCA suggests that the highest score-yielding variable for the first component should be selected for a logistic regression (LR). This LR produced a solution in which H2_LA2 was again selected as the most useful variable to identify both sexes regardless of taxon (Fig. 3). The LR analysis showed that the probability of correctly identifying a female based on the acetabular height and length was higher than 80% when the ratio was < 0.2 and the same applies to identifying most of the males, when the H2_LAR2 ratio was > 0.3. Although most of the acetabulae whose ratio was comprised between 0.2 and 0.3 belonged to males, this portion of the ratio range was more ambiguous in sex identification.

4. Discussion

The present work has provided some verification of which measurements are best able to distinguish sex in bovid osteological assemblages when using the pelvic acetabulum.

Most of the sexing studies have focused on non-Palaeolithic contexts (e.g., Davis et al., 2012; McGrory et al., 2012; Munro et al., 2011; Prummel and Frisch, 1986; Svensson et al., 2008; Tchernov et al., 1990; Zeder, 2001). Only a few attempts to sexing carcasses have been applied to Palaeolithic assemblages. For example, Weinstock (2000) reconstructed sex profiles of reindeer

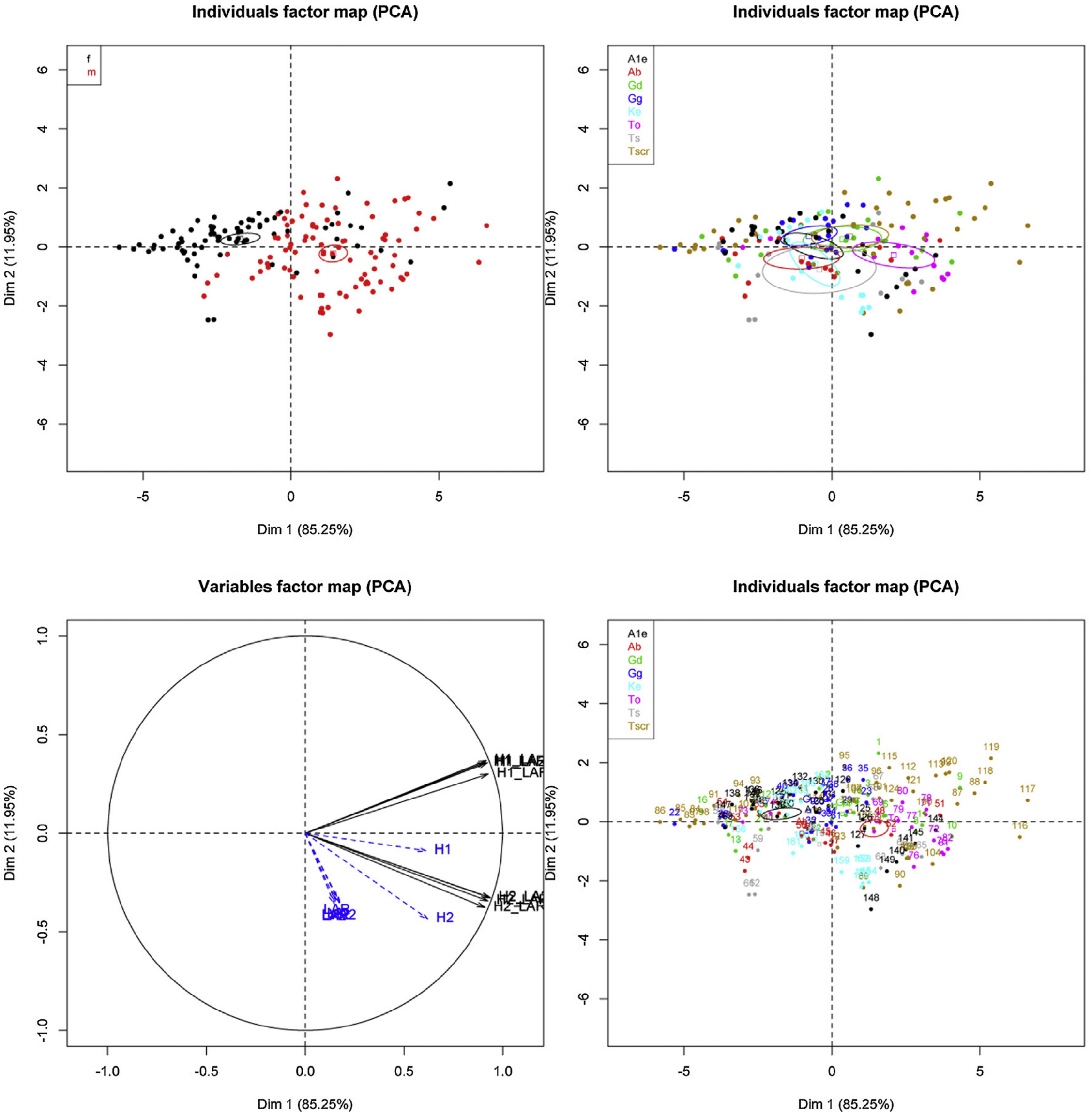

Fig. 2. (Color online.) Principal component analysis (PCA) of the 8-taxon bovid sample, showing clear separation of both sexes (upper left), with complete overlap when the sample is displayed according to taxon (upper right). The variables factor map (lower left) shows how most variables contribute to the first component. The individuals factor map (lower right) displays each acetabulum measured according to taxon and the alpha bags show that both sexes are completely separated. Key: f, female; m, male; A1e, *Aepycerus melampus*; Ab, *Alcelaphus buselaphus*; Gd, *Gazella dorcas;* Gg, *Gazella granti;* Ke, *Kobus ellipsiprymnus;* To, *Taurotragus oryx;* Tscr, *Tragelaphus scriptus;* Ts, *Tragelaphus strepsiceros.*

Fig. 2. (Couleur en ligne.) Analyse en composantes principales d'un échantillonnage de 8 taxons de bovidés, montrant une séparation nette entre les deux sexes (en haut à gauche), avec un complet recouvrement quand l'échantillonnage est présenté selon le taxon (en haut à droite). La carte de facteur des variables (en bas à gauche) montre combien la plupart des variables contribue à la première composante. La carte de facteur des individus (en bas à droite) présente chaque acetabulum mesuré selon le taxon et les sexes complètement séparés, d'après les ellipses de confiance. Signification : f, femelle ; m, mâle ; A1e, *Aepycerus melampus* ; Ab, *Alcelaphus buselaphus* ; Gd, *Gazella dorcas* ; Gg, *Gazella granti* ; Ke, *Kobus ellipsiprymnus* ; To, *Taurotragus oryx* ; Tscr, *Tragelaphus scriptus* ; Ts, *Tragelaphus strepsiceros*.

at the Late Glacial Site of Stellmoor (Northern Germany). Arceredillo et al. (2011) sexed *Rupicapra* carcasses at Valdegoba Cave (Burgos, Spain) with the aim of verifying if Neanderthals had sex preferences when they hunted chamois, showing that they killed more males than females. D'Errico and Vanhaeren (2002) elaborated a method for identifying canines from red deer to know the sex of perforated canines used as personal ornaments.

The present work has taken Greenfield's (2002) and Von den Driesch's (1976) studies, as a foundation. According to Greenfield (2002), H1 provides clear results and allows sexing animals successfully. The present study supports this statement, H1 being one of the measurements that is more useful to separate sex. However, Greenfield (2002) points out that H2 yields less satisfactory results than H1, and he considers it difficult to measure and less suitable to

Table 2
Loading scores of the correlation values and their significance of the PCA. See key to variables in the main text.
Tableau 2
Scores de charge des valeurs de corrélation et leur signification dans l'analyse en composantes principales. Se reporter aux variables dans le corps du texte.

$Dim.1	Correlation	*P* value	$Dim.2	Correlation	*P* value
H2_LA2	0.9366728	4.304780e−77	H1_LA	0.3684251	9.643772e^{-07}
H2_LA	0.9363104	6.789502e−77	H1_LAR2	0.3595818	1.819268e^{-06}
H1_LAR	0.9267806	4.523151e−72	H1_LA2	0.3571098	2.165138e^{-06}
H2_LAR2	0.9252839	2.255983e−71	H1_LAR	0.3002408	8.074854e^{-05}
H1_LA2	0.9220606	6.427515e−70	LAR	−0.3254904	1.769614e^{-05}
H1_LA	0.9170026	9.308281e−68	H2_LA2	−0.3260898	1.704110e^{-05}
H1_LAR2	0.9113372	1.703455e−65	H2_LA	−0.3276666	1.542557e^{-05}
H2_LAR	0.9104685	3.671126e−65	H2_LAR2	−0.3431643	5.625825e^{-06}
H2	0.6201422	4.007300e−19	LA	−0.3454030	4.841061e^{-06}
H1	0.6110027	1.812467e−18	W2	−0.3512011	3.262953e^{-06}
W2	0.1749704	2.372158e−02	LAR2	−0.3519940	3.089710e^{-06}
LAR2	0.1709824	2.715530e−02	LA2	−0.3574867	2.108634e^{-06}
LAR	0.1596268	3.934398e−02	H2_LAR	−0.3770805	5.086222e^{-07}
LA	0.1521548	4.965212e−02	H2	−0.4338692	4.701933e^{-09}

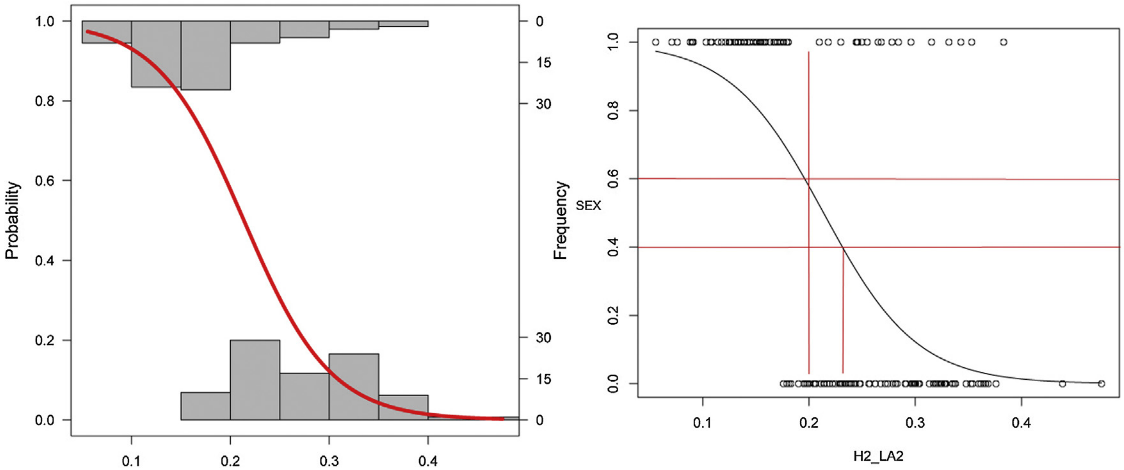

Fig. 3. (Color online.) Results of the logistic regression showing the differentiation threshold of males and females, using the H2_LA2 ratio. Males are coded as "0" and females as "1".

Fig. 3. (Couleur en ligne.) Résultats de la régression logistique montrant le seuil de différenciation mâles/femelles utilisant le rapport H2_LA2. Les mâles sont codés « 0 » et les femelles « 1 ».

separate sex. From our point of view, according to the results of the present work, H2 is not only slightly better than H1 to distinguish sex, although the difference between both measurements is small, but also H2 is the measurement that is taken better, thus more easily avoiding measuring errors. When H1 is measured with a calliper, there is the possibility that the arm does not rest on the centre of the acetabulum. H2 provides a more stable resting point to take measurements. Given that the calliper arms are adjusted to the wall, the possibility of displacement is lower.

In addition, we consider H2 a "visual measurement" because it is the only indicator that at first sight allows the analyst to determine sex owing to, as a rule, the medial wall of the acetabulum being lower in females and higher in males, as Greenfield (2002) noticed. Another advantage of this measurement is that it can be applied in fragmentary remains, since we only need the medial wall of the acetabulum to be preserved (Greenfield, 2002), whereas for the rest of the measurements, it is necessary to have the complete acetabulum.

LA and LAR measure the length of the acetabulum. They are measurements suggested by Von den Driesch (1976) and also used by Greenfield (2002). If they are applied in isolation, they are less effective than in combination with H1 and H2 (in the form of a ratio) to distinguish sex. Additionally, LA and LAR have certain disadvantages, as noted by Von den Driesch (1976), who recommends using LA for those species that have a lip in the acetabulum, and LAR for those species with no lip.

5. Conclusions

The importance of knowing the sex of the carcasses that archaeologists find in their assemblages can play an important role in their interpretation of sites, carcass acquisition strategies and subsistence patterns. The often fragmentary condition of most bones in the assemblages, especially those from the Palaeolithic period, or the absence of morphological characteristics such as horns, should not be an obstacle in the reconstruction of sex.

Several authors have considered the importance of pelvic features to identify sex (Boessneck et al., 1964; Davis, 1987; Greenfield, 2002; Grigson, 1982; Lemppenau, 1964 Munro et al., 2011; Prummel and Frisch, 1986; Von den Driesch, 1976; Von Leithner, 1927). Thus, the present study has taken Greenfield's study (2002) and his complete set of measurements in order to distinguish sex through certain measurements of the acetabulum and has created a standardized methodology that could be applied to bovids regardless of taxon. Considering the results of this work, we conclude that the medial acetabular wall is one of the most sensitive indicators of sex, as Greenfield (2002) noticed, and therefore some of the most useful measurements are those taken in this part of the pelvis.

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